POWER PLANT ENGINEERING

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Contents of this Issue

Page

Power for Finishing Silk....1130

Chemical Analyses in Embrittlement Studies. By Frederick G. Straub....1136

Turbine Expansion Lines of Actual Machines....1141

Diesel Engines as Peak Load Units. By S. A. Hadley...1144

Parallel Operation of A. C. Generators. By E. H. Stivender....1147

A Strenuous Steam Engine Repair Job. By George H. Wallace....1149

Spillway Waste Power Salvaged....1151

2500-Lb. Testing Boiler. By D. Robert Yarnall....1153

Steel Floor of Interlocked Structural Shapes....1154

Water Cooling. By L. M. Jordan....1155

Wire Rope Use and Care....1157

Letters Direct from the Plant: Power Loss in Motor Connections. Brine Spray Refrigeration. Emergency Dutchman on a Piping Job. Novel, but Sure, Test for Pipe Lines. Exhauster for Oil Fumes....1159

Questions and Answers: Which Way Should Belt Run? Reconnecting Two-Phase Generator for Single Phase. Steam Consumption from Indicator Card....1161

Editorial Comment: Vacuum Tubes, Electrons, Kilowatt-Hours and the Gold Standard. Welding, a New Industrial Tool. The Engineer as Purchaser. Stability of the Power Industry....1162

Weldolets and Thredolets....1164

Ball-Bearing Stuffing-Box....1164

Bourdon Tube Pilot Valve Control....1165

New Straight Flow Valve....1165

Asphalt Plank for Roadway Platform....1165

Pyrometers for Boiler Plants....1166

New Chemical Feeder....1166

Ice Plant Model Shows Modern Equipment....1167

New Portable Belt Conveyor....1167

News Notes....1167

Books and Catalogs....1168

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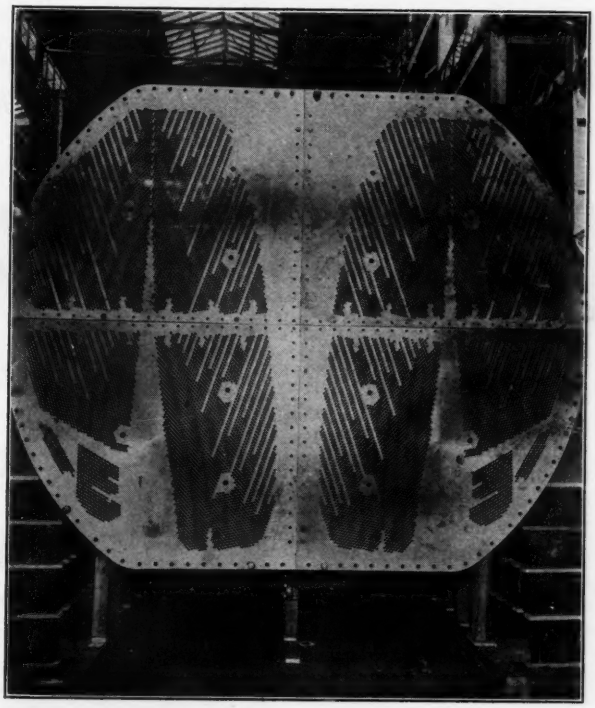


Flies' Eyes

IF YOU HAVE glanced at the above photograph, you have seen a de-magnified worms-eye view of the optics of a condensiatus tubus sheetus. Statisticians have been working for months, since the discovery of the likeness in appearance of the above eye to a condenser tube sheet, calculating that if it *was* a condenser and the tubes were the same length as the insect and of the same proportional diameter, the condensing surface would be 101,000 sq. ft. and if these tubes were laid end to end they would reach from New York to Philadelphia or from Philadelphia to New York, depending upon, of course, in which municipality the statistician resided.

This rare specimen was discovered hiding beneath the roof of the Worthington Pump and Machinery Co. and is destined to be placed in the Hudson Avenue generating station of the Brooklyn Edison Co.

As you will observe by studying the photograph above, the eye is compound, much the same as that of a house-fly and statisticians have also carefully calculated that, if each pair of facets were owned by a human observer, there would scarcely be enough observers to collect the data that will appear in the December 15 Review number of Power Plant Engineering.

Power For Finishing Silk

Highly fluctuating load requirements at new plant of the Sunbury Converting Works at Belvidere, N. J. satisfied by new 3000 kv.a. power plant.

IN THE CONVERSION of raw woven silk into the finished salable product a number of special finishing operations are necessary. These operations which include weighting, dyeing and finishing, are largely of a chemical nature, subject to rather delicate control and requiring a highly continuous and reliable supply of steam and electric power.

For this reason, the power plant serving the new plant of the Sunbury Converting Works at Belvidere, N. J., was designed to incorporate a high degree of reliability, consistent, of course, with the requirement for economy of operation to which plants of this character must conform.

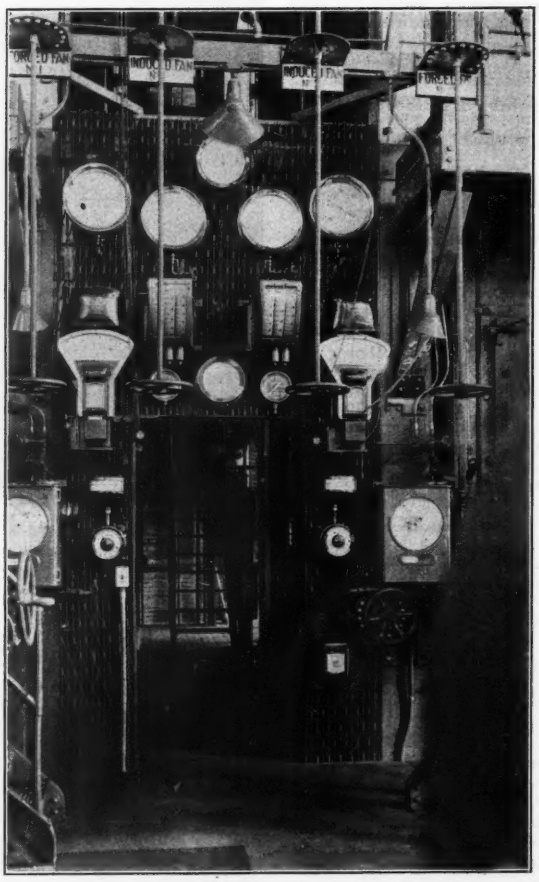


FIG. 1. BOILER INSTRUMENT STATION

This plant was placed in operation some time ago coincidently with the starting of the new plant. It is an excellent example of modern industrial power plant practice, using standard equipment which has proven its worth in established practice. During the year or more that it has been in operation, it has given excellent service and has fully justified the owners' decision to generate their own power. As in all power plants, however, it must be pointed out that the fine performance of this plant is due not alone to the character of its design but also, and in perhaps a larger measure than usually assumed, to the ability and progressiveness of the operating staff. This is particularly true of this plant. The operation is carried out on a thoroughly systematic basis and an excellent system of records is maintained by means of which all factors are subject to close inspection and rigid comparison.

Before we proceed with a more or less detailed discussion of this power plant, a brief general picture will be of interest. It consists essentially of two 825-hp. Badenhausen boilers, fired by the unit system of pulverized coal and delivering steam at a pressure of 340 lb. and a total temperature of 450 deg. to two 1563-kv-a. Westinghouse extraction type turbo-alternators. These are bled at 110 lb. and exhaust against 30-lb. back pressure, both the bled and exhaust steam being used for process purposes in the factory.

This equipment is contained in a separate brick and steel building apart from the factory proper but connected to it by overhead steam and electric transmission lines. The boilers are served by two steel stacks, one for each boiler, mounted directly over the boilers. These are 7 ft. in diameter and extend 75 ft. above the fan floor. The architectural features of the building, although not elaborate, are pleasing and harmonize well with the other buildings constituting the plant.

The turbine room floor and the boiler room operating floor are on the same level, but the two divisions are separated by means of the usual common wall between. A spacious basement affords ample room for boiler feed, vacuum and service pumps and for the ash disposal

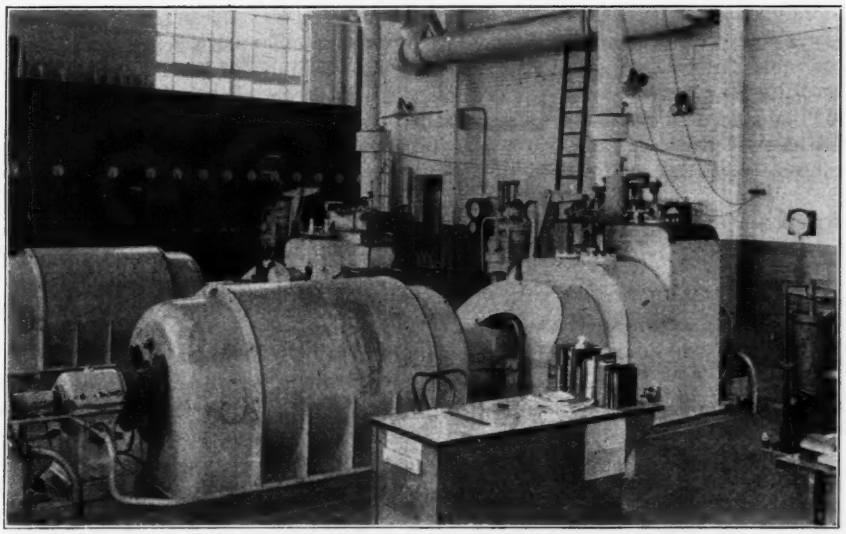


FIG. 2. A GENERAL VIEW IN THE TURBINE ROOM AT THE SUNBURY CONVERTING WORKS

equipment. The latter is the Allen-Sherman-Hoff Hydrojet system using movable nozzles.

Located on the banks of the Delaware River, the plant is assured of an ample supply of water for both boiler feed and process purposes and a spur from the Pennsylvania Railroad guarantees an uninterrupted coal supply. Coal is delivered into a track hopper underneath a trestle adjacent to the boiler house from which it is delivered either to a storage yard by a drag scraper, or to the boiler house by a system of flight conveyors. At the boiler house, it passes through a single roll crusher and finally is carried to overhead coal bunkers in the boiler rooms by a pivoted bucket conveyor. All coal handling equipment, including the coal bunkers and the weigh larries in the boiler room, was designed and built by Link-Belt Co.

In the boiler room the coal is removed from the overhead bunkers by means of two electric weigh larries which deliver to either of three Riley "Atrita" unit pulverizers. Two larries are provided instead of one in order to insure reliable service under all conditions. An interesting feature of the larry installation is the small traveling crane installed between the larries and running on the same rails, which handle the pulverizing equipment below whenever it becomes necessary to do so.

From this, it must be evident that the coal handling system is quite simple and well insured against interruption due to failure of equipment. Little coal storage capacity is provided. Although an outdoor storage pile is maintained, no attempt is made to store any large amount of coal. The coal used deteriorates rapidly when exposed to the open air, so, since it is easily obtainable only a small supply is kept on hand.

Features of the Boiler Room

Throughout, the power plant has been designed so as to provide ample space around all equipment so as to make it easy of access in case of repair or overhaul and

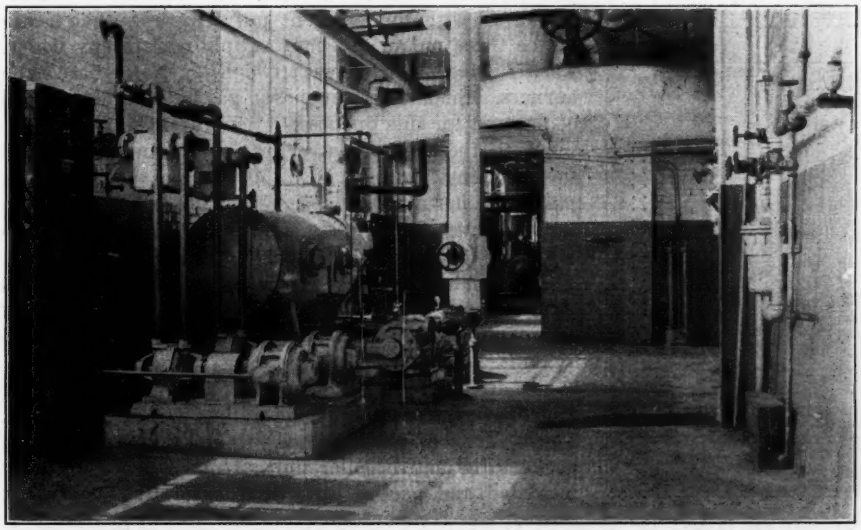


FIG. 3. VACUUM PUMP INSTALLATION FOR HEATING SYSTEM INSTALLED IN BASEMENT OF POWER PLANT

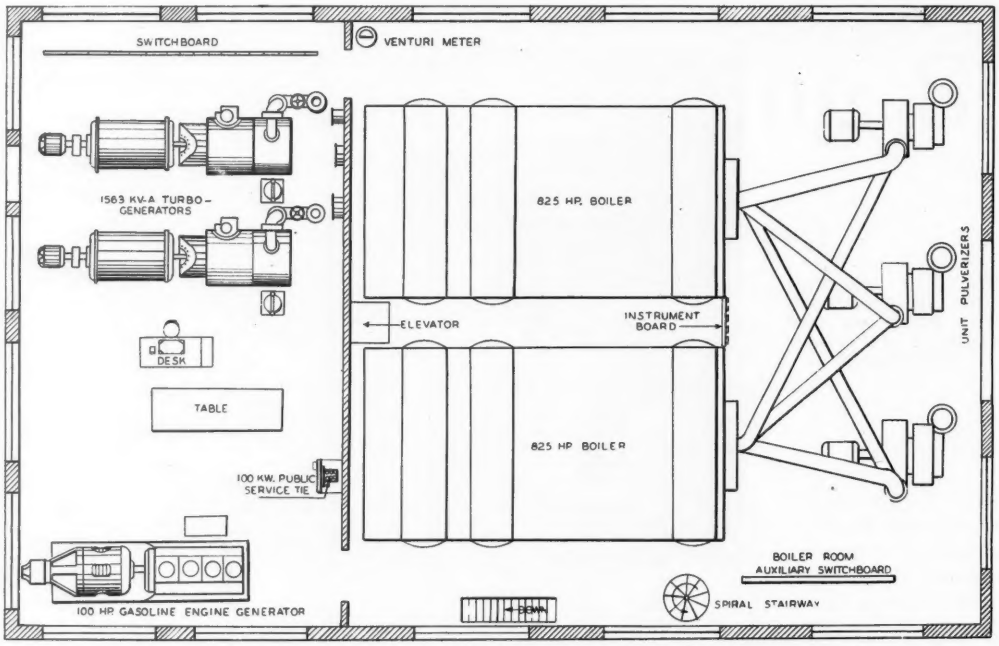


FIG. 4. PLAN SHOWING ARRANGEMENT OF EQUIPMENT

to make operation convenient. This is as true of the boiler room as it is of the turbine room. Large windows on three sides flood the boiler room with an abundance of daylight and wide aisles and clearances inspire the operators to keep the plant clean and neat. To aid in the latter, an Allen and Billmyre Co. vacuum cleaning system is provided in the basement. Another convenience which is greatly appreciated by the operators and which is not always found in this type of power plant is the automatic electric elevator installed in the boiler room. This elevator, a product of the Warsaw Elevator Co., runs the full height of the boiler house, from the basement to the fan room.

The two boilers which constitute the present steam generating equipment are set singly with the three pulverizers directly in front as shown in the plan and in the accompanying photographs. They are of the Badenhausen, high efficiency type, each consisting of an 825 hp. Badenhausen preheater type boiler with water-cooled furnaces, a Carl steel clad setting and an air heater arranged for powdered fuel firing.

FIG. 5. EXTERIOR VIEW OF POWER PLANT

In this type of boiler, as may be noted from the sectional view, the heating surface is divided into two stages, one in which the water is preheated by the waste gases and the other in which steam is produced.

Each boiler is rated at 148,000 lb. of steam per hr. although at the present time the average total load runs approximately 55,000 lb. per hr. Steam is produced at 340 lb. gage (the safety valves being set to pop at 360 lb.) and is superheated about 20 deg. not by a separate superheater but by a special design of the dry steam tubes. Fifty-three hundred square feet of water-cooling is used in the boiler. The preheater has 12,000 sq. ft. of surface and the integral economizer 4200 sq. ft.

As already stated, these two boilers are fired by three No. 5 Riley "Atrita" pulverizing units driven by General Electric induction motors. The burners are interconnected with the different pulverizers so that either of the three pulverizers may supply coal to any boiler. Each furnace is fitted with two Riley No. 4 flare type burners. For starting purposes, gas is used, bottled gas being used for this purpose.

With these three pulverizers, the plant has a total fuel burning capacity of 22,500 lb. per hr., for each pulverizer has a rated capacity of 7500 lb. per hr. Thus far, however, in no instance has it been necessary to use more than two pulverizers to carry the load.

The coal used is a Clearfield County coal which is about 23 per cent volatile. This is pulverized so that approximately 80 per cent passes through 200-mesh screen.

As already stated, the furnaces are completely water cooled, sides, front and bridge wall as well as the bottom. These furnaces are enclosed in a steel casing which encloses the entire boiler unit. This casing is properly insulated and backed up with tile forming a compact setting, free from cracks.

One forced draft and one induced draft fan is installed for each boiler. These are installed above the boilers where connections to the air heater and stacks are most convenient. The forced draft fans, are Sturtevant Turbovane units, Design 5, size 100, driven by 440-v., 100-hp. G. E. induction motors. The induced draft fans, also are Sturtevant units, but are of the multivane type, each driven by a 300-hp. G. E. motor.

An interesting feature about the fan installation is the method of control. The induction motors are of the wound rotor type using the secondary resistance method of speed control. In any installation where this form of control is used, it is, of course, most convenient to mount the resistance grids and the controllers as close to the motors as possible. At the Sunbury plant this, of course, means that the controllers and grids be placed on the fan floor and this is where they are located. At the same time, for most convenient operation it is desirable that the speed of the fans be adjustable from the operating floor.

While this could be effected by a system of electrical remote control, it would be expensive, so, instead, at this plant the controllers on the fan floor are operated directly from the operating floor by means of long extension rods attached to the shafts of the controllers. These shafts are operated by handwheels from the instrument panel in front of the boiler. These handwheels may be seen in Fig. 1. In order to provide the operator with an indication as to the position of the controller shafts, they are fitted with a series of contacts which connect with neon light indicators at the operating position. Thus the operator is at all times certain as to the position of the controller handle.

The boilers are fully equipped with the most modern types of fittings and accessories. They are provided with Wager smoke indicators, Copes feedwater regulators, Reliance water columns, Diamond soot blowers, Yarway tandem blowoff valves, Schutte & Koerting stop and check valves, Ashton safety valves as well as a full complement of indicating and recording instruments. The latter are mounted on a grillwork installed between the two boilers, at the front where they are easily seen by the operators.

On this grillwork are mounted the following instruments:

2—Ranarex CO_2 indicating and recording meters
2—Bailey multi-point draft gages, indicating the draft pressure in the furnace, in the uptake, and the primary air pressure
2—Gages showing the position of the feedwater regulator valves
2—Brown Instrument Co. electric pyrometers
2—Bailey boiler meters
2—Foxboro, main steam pressure gages, one for each boiler
1—Feedwater pressure gage
1—Pressure gage showing the pressure in the line between the deaerating heater and the boiler feed pumps
1—Brown recording pressure gage
1—Electric clock

As may be noted from Fig. 1, all these instruments are conveniently placed in full view of the operators

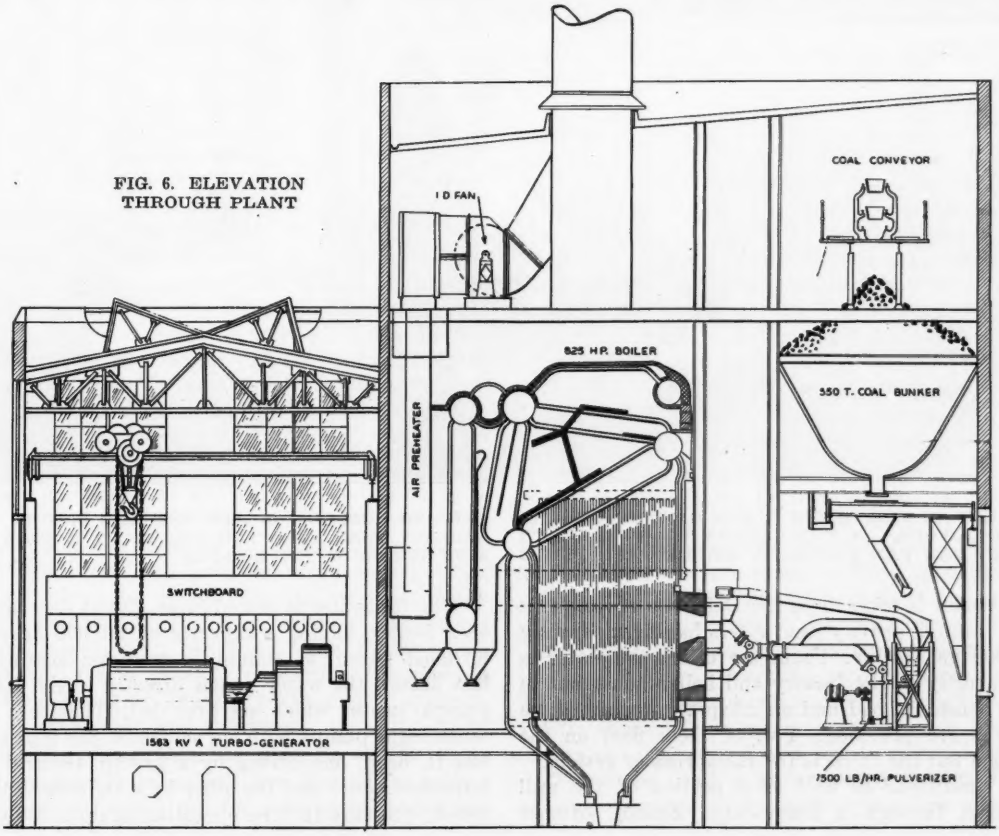


FIG. 6. ELEVATION THROUGH PLANT

and within convenient range of the main controls. Mounting them on a grillwork, ,which, by the way, is built of a few sections of subway grating has the advantage of being inexpensive and at the same time not obstructing the passage of light between the boilers.

All water used at the Sunbury plant including the boiler feedwater is taken from the Delaware River. This is filtered through gravity sand filters having a capacity of 6,000,000 gal. a day. From the filters the water is pumped directly to the factory and boiler house but to provide a constant head and an adequate storage, three tower tanks are provided. Two of these float on the main system but the third is for the sprinkler system.

Boiler feedwater as well as a portion of the mill water passes through a Paige-Jones Zeolite softener system. This is practically the only treatment given the water. To guard against corrosion or pitting, all water surfaces in the boilers, the water walls, drums, etc., are coated with Apexior. Also to maintain the concentration low, the boilers are provided with the Permutit system of continuous blowdown.

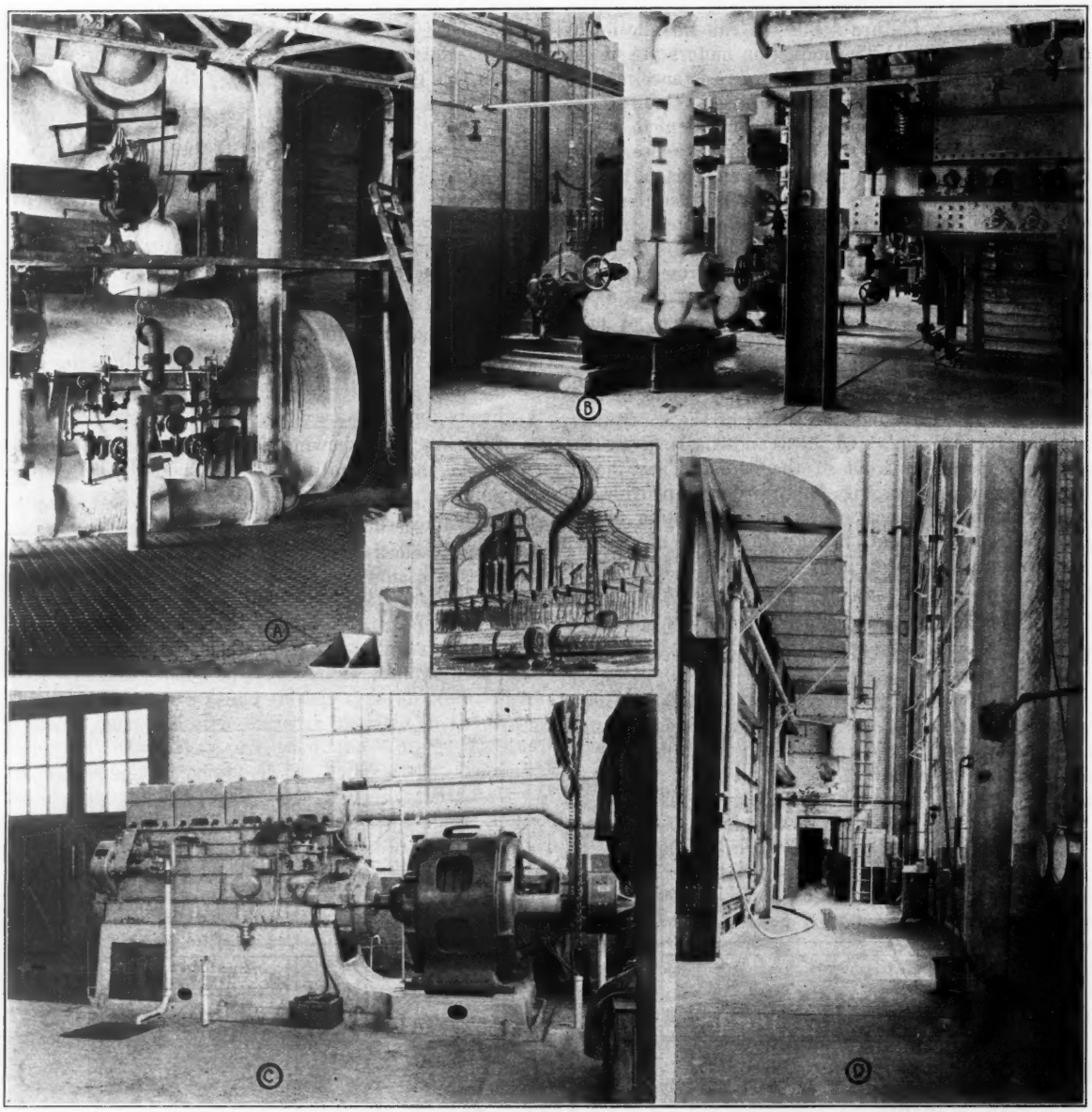


FIG. 7. VIEWS IN THE POWER PLANT OF THE SUNBURY CONVERTING WORKS. A. THE DEAERATING FEEDWATER HEATER IN THE FAN FLOOR. B. BOILER FEED PUMPS AND ASH HOPPERS. C. THE GASOLINE ENGINE GENERATOR SET USED FOR STARTING UP. D. A VIEW ALONGSIDE OF ONE OF THE BOILERS

The feedwater is heated in an Elliott deaerating type open heater, having a capacity of 210,000 lb. per hour. Exhaust steam, of course, is used for heating. From this heater, the water passes directly to the boiler feed pumps, two of which are provided. These are DeLaval centrifugal pumps with capacities of 350 g.p.m. against 924 ft. head, one driven by a 150-hp. General Electric induction motor and the other by a DeLaval 3100-r.p.m., 340-lb. pressure turbine operating against 30-lb. exhaust

pressure. Two simplex water meters are provided, one on the main feed line and the other on the continuous blowdown system.

The feedwater supply to the boilers is regulated by Copes feedwater regulators.

An interesting feature of the water supply system is the matter of testing. In the factory, as has been intimated, the processes are of a rather delicate chemical nature and it is necessary that only water of absolutely known quality be used. So the water is given many tests, both the factory water and boiler water being subjected to 36 different tests. A continuous record of the hydrogen ion concentration is kept.

Turbine Room

As was true of the boiler room, the turbine room is simply and attractively designed. The two turbo-generators are set parallel to each other with their steam ends toward the boiler room wall. They are supplied from a common header by overhead piping. The electrical switchboard occupies the entire side of one end of the room.

The two generating units are Westinghouse machines each consisting of a 1563-kv-a., 480-v., 3-phase, 60-cycle generator direct connected to a 340-lb. pressure bleeder type non-condensing turbine, having direct connected exciters. The generators use the open system of ventilation, a clean supply of air being assured by the use of National air filters.

These machines are run alternately for one week at a time, one machine having ample capacity to carry the normal plant load. This practice makes it possible to overhaul one machine while the other is running. Ordinarily, however, little overhauling is necessary; indeed, the first machine was run for ten months before it was taken down and then it was found to be in excellent condition.

In addition to these two generating units a gasoline engine driven starting set is provided. Since the pulverizers as well as many other essential auxiliaries are electrically driven, it is necessary to have a source of power available when all the boilers are shut down and the plant is to be started up. While the plant is tied in with the local public service company system, this tie is limited to a 100-kw. demand and this is not enough for starting purposes, since this requires from 200 to 250 kw. Starting, therefore, is accomplished by means of a Sterling, Viking gasoline engine rated at 565 hp. direct connected to a 400 kv-a. Westinghouse generator. This machine has a direct connected exciter, is entirely self contained, and is always ready for instant operation. It operates at 1200 r.p.m.

Current generated at 440 volts is controlled by a 17-panel vertical, General Electric switchboard. This board consists of one regulator panel containing a G. E. type TA-125, Form K-3 automatic voltage regulator, one 400-kw. alternator panel (starting set), one blank panel for a future generator, two generator panels, one boiler room feeder panel, one pump house feeder panel, and 10 general feeder panels. In addition, the board is fitted with a swinging bracket containing a synchroscopic frequency meter and voltmeters.

Distribution throughout the plant is at 440 v. by means of overhead distribution lines. Most of the motors operate directly at 440 v. but for a few small ones using lower voltage and for lighting service, step down transformers are provided at the load centers. The electric power to each department in the factory is metered separately.

In the boiler room, a special switchboard is provided for the control of all boiler room motor driven auxiliaries.

Operation and Maintenance

While the plant has never been operated at its full capacity, in the year that it has been in service, it has operated perfectly satisfactorily. Boiler efficiencies have averaged 78 per cent, which, considering the light loads available, is good practice. On the average, the evaporation varies between 10 and 12 lb. of water per pound of coal.

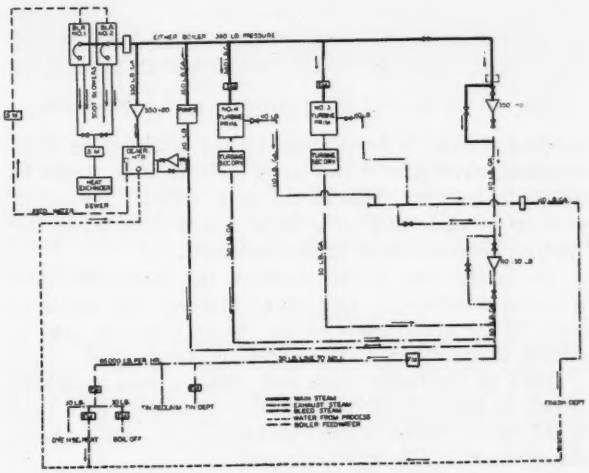


FIG. 8. FLOW DIAGRAM SHOWING STEAM AND WATER FLOW IN THE PLANT

Both steam and electricity to the various departments are metered, separate flow meters being installed on the various steam lines. In the turbine room four Republic flow meters measure the total steam output of the plant. Two of these are provided for the two turbines and one each for the 30 and 110-lb. steam lines to the factory respectively. All flow meters are tested by the manufacturers' test men once every three months. Foxboro recording vacuum gages and thermometers are installed.

As has been stated, the turbines exhaust at 30 lb. pressure and steam is bled at 110 lb. Under "non-bleeding" conditions, the turbines have a water rate of 50 lb. per kw. Thus at from 600 to 700-kw. load, up to 35,000 lb. of 30-lb. steam is available. If this quantity is insufficient, however, a Foster reducing valve is provided reducing the steam pressure from 350 to 110 lb. and this in turn is reduced to 30 lb. by another Davis reducing valve. The bleeder lines from the turbine are equipped with Schutte & Koerting nonreturn valves. The exhaust steam and the bleeder steam are carried to the factory by two overhead, outdoor steam lines, one a 20-in. line for 30-lb. steam and the other a 10-in. line for 110-lb. steam. This line is installed on a line of steel towers and is equipped with large expansion loops.

The steam load is an extremely fluctuating one as can be seen from the accompanying flow meter record

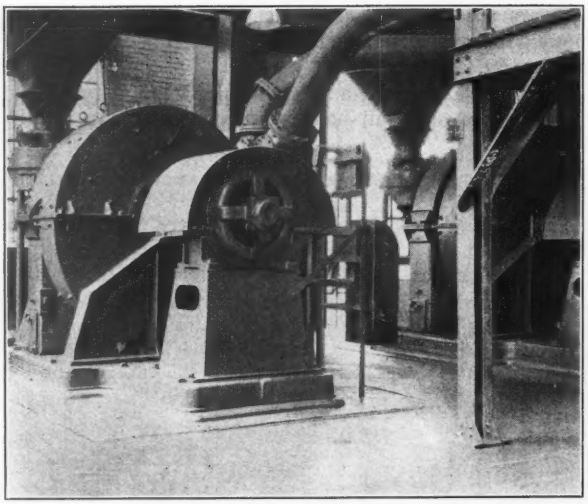


FIG. 9. THREE UNIT PULVERIZERS ARE INSTALLED

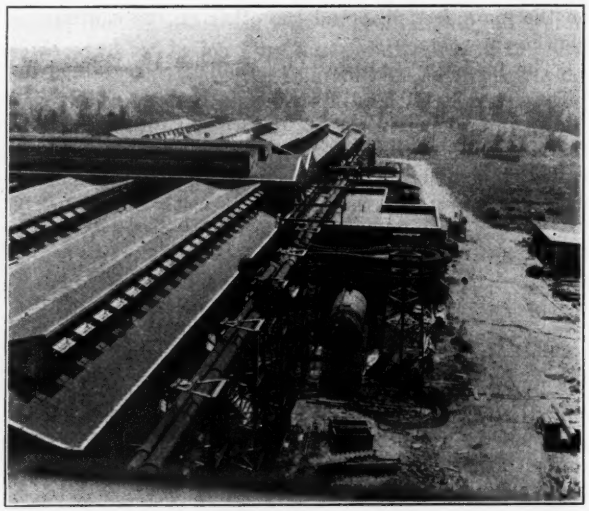


FIG. 10. A VIEW OVERLOOKING THE FACTORY SHOWING THE OVERHEAD STEAM LINES AND EXPANSION LOOPS

showing one day's fluctuations on the 30-lb. steam line. At times, particularly over week ends, it often drops to 20,000 lb. per hr. This is the most difficult operating problem to meet and to a large extent determines the limiting characteristics of the coal used.

As in the case of the turbines, the boilers also are operated alternately. Insofar as possible, one boiler is operated for about *eight* to *ten* weeks, then the load is shifted to the other, and the first one overhauled.

Both in the boiler room and turbine room a careful record is kept of all commodities consumed and produced, all of which is incorporated in the daily power house report to the superintendent.

On the whole, this is an excellent example of industrial power plant practice and is one which should amply repay the owners for the investment involved.

In a plant of this type where a great amount of exhaust steam is used, where a certain amount of electrical energy is required and where the balance between this steam load and electrical load is proper, this type of plant is ideally suited.

In concluding this article, we wish to extend credit to the officers and engineer of the Sunbury Converting Works for their courtesy and assistance in supplying us with the information on which this article is based.

Chemical Analyses in Embrittlement Studies[1]

LABORATORY ANALYSIS SHOWS THAT A.P.H.A. AND MODIFIED WINKLER METHODS GIVE RELIABLE RESULTS WHEN USED ON BOILER WATERS FOR EMBRITTLEMENT STUDIES. BY FREDERICK G. STRAUB[2]

IN THE WORK conducted by the author in determining the cause and prevention of embrittlement[3], attention was called to the importance of the accurate determination of the carbonate and hydrate alkalinity in boiler water. This was due to the fact that the curve shown in Fig. 1[4] had been evolved through correlation of laboratory and plant data. At the time these data were collected, care was taken to ascertain that the values reported were correctly determined; however, the accuracy of these data have been recently questioned[5], and the author would like to explain in detail the procedure used in obtaining them and show the accuracy of the methods employed.

In obtaining the hydrate and carbonate alkalinity of the boiler waters which were taken from plants experiencing embrittlement, as well as from those not experiencing it, one must consider that these waters were free from phosphate and in the majority of cases contained appreciable amounts of hydrate and carbonate alkalinity with low organic matter. Table I gives the results of the analyses of several typical embrittling boiler waters as well as the nonembrittling types that are typical of the waters used in obtaining the data plotted in Fig. 1. These results will serve to give a rough idea of the amounts of hydrate and carbonate present in the waters analyzed. The sodium carbonate was almost always above 100 parts per million and the hydrate higher than 300 p.p.m.

Procedure followed in analyzing these waters is commonly referred to as the A.P.H.A. method, since it has been adopted as a standard method by the American Public Health Association. The method as published by the Association[6] states:

[1]Data from research being conducted in the Engineering Experiment Station at the University of Illinois and financed by the Utilities Research Commission of Chicago. Publication authorized by Dean M. S. Ketchum, Director of the Engineering Experiment Station.

[2]Special Research Assistant Professor in Chemical Engineering, University of Illinois.

[3]Bulletin No. 216, Engineering Experiment Station, University of Illinois, "Embrittlement in Boilers" by Frederick G. Straub. See Power Plant Engineering, page 190, Feb. 1, 1931, for abstract of this bulletin.

[4]Figure 41, page 77, Bulletin No. 216—(3).

[5]Hecht and McKinney, "Significance of Alkalinity in Embrittlement Studies," Power Plant Engineering, June, 1931.

[6]Standard Methods of Water Analyses, 6th Edition, 1925, American Public Health Association, New York.

TABLE I. ANALYSIS IN P.P.M. OF TYPICAL BOILER WATERS FROM WHICH DATA WERE OBTAINED IN EMBRITTLEMENT RESEARCH

Type of Water	Embrittling (A to E)					Non-Embrittling (F to J)				
Boiler Water	A	B	C	D	E	F	G	H	I	J
Sodium Hydroxide, NaOH	3720	1090	1700	880	550	560	380	620	1824	1684
Sodium Carbonate, Na_2CO_3	1260	180	580	280	140	1180	290	135	3986	8900
Total Alkalinity as Na_2CO_3	6200	1630	2840	1450	870	1970	795	955	6405	11130
Sodium Sulphate	975	256	1420	62	43	168	2000	2060	828	18060
$\frac{Na_2CO_3}{NaOH}$	0.34	0.17	0.34	0.32	0.26	2.1	0.76	0.22	2.18	5.28
$\frac{Na_2SO_4}{NaOH}$	0.26	0.24	0.85	0.07	0.08	0.30	5.26	3.32	0.45	10.70
$\frac{Na_2SO_4}{\text{Total Alkalinity}}$	0.16	0.16	0.50	0.04	0.05	0.08	2.52	2.16	0.13	1.62
$\frac{Na_2CO_3 + Na_2SO_4}{NaOH}$	0.60	0.40	0.70	0.39	0.33	3.8	7.35	3.54	2.63	16.00

"The alkalinity is determined by titration with a standard solution of a strong acid to certain standard datum points or hydrogen ion concentrations. Indicators are selected which show definite color changes at these points.

"Since dilute bicarbonate solutions have a hydrogen ion concentration of about $1 \times 10^{-8.0}$ (or pH 8.0) and dilute carbonic acid solutions a hydrogen ion concentration of $1 \times 10^{-4.0}$ (or pH 4.0), these are chosen as the datum points and indicators should be selected which show definite color changes at about these points. The amount of standard acid required to bring the water to the first point measures the hydroxide plus one-half the normal carbonates, and the amount to bring it to the second point corresponds to the total alkalinity."

Hecht and McKinney have outlined what they term an abridged equilibrium method which they claim will overcome the difficulties which they say are encountered in using the A.P.H.A. method for evaluating ions in water. This method consists of determining the pH value first; then with a separate sample titrating with a strong acid to a pH of 8.5 using Thymol Blue; and then, on a third sample titrating to a pH of 5.0 using Brom-Cresol Green, the end points to be determined by means of a special color comparator. The carbonate is then calculated from these data.

End points selected for the titration of the solution by the abridged equilibrium method are practically identical with those selected for the A.P.H.A. determination. In order to see the real difference between these two procedures, a test was made on four solutions of known compositions having carbonate, hydrate, chloride and sulphate present, and four boiler waters free from phosphate and having a hydrate and carbonate alkalinity similar to that encountered in boiler waters used in the embrittlement calculations. These solutions

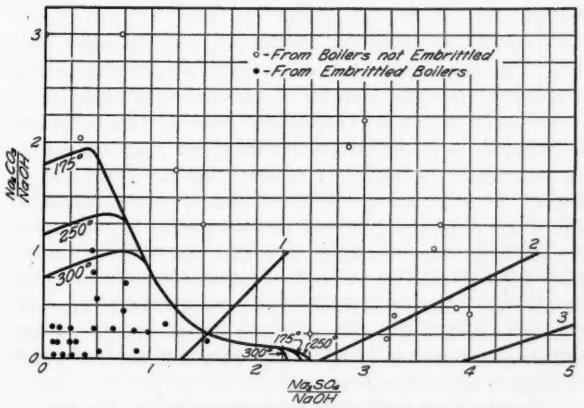


FIG. 1. RATIOS TO PREVENT EMBRITTLEMENT

TABLE II. AVERAGE Na_2CO_3 CONTENT DETERMINED IN P.P.M.

Sample Number	By CO_2 Evolution	By A.P.H.A. Method	By Abridged Equilib. Method	% Error in A.P.H.A. Method	% Error in Equilib. Method
1	89	84	84	-5.5	-5.5
2	113	124	116	10.0	2.7
3	320	323	329	1.0	3.0
4	1568	1542	1562	-1.7	0.1
108	493	506	539	2.6	9.4
109	6675	6865	7215	1.3	6.5
110	648	705	732	9.0	17.0
111	495	536	587	8.2	18.5

were analyzed by the A.P.H.A. and the abridged equilibrium methods, in duplicate by three analysts.

Results of the average of the analyses are given in Table II. Thus, in the four synthetic waters having a sodium carbonate composition from 89 to 1568, the relative accuracy of both methods falls within the experimental errors. In the boiler waters the A.P.H.A. gave more accurate results in all four samples. The errors encountered in the equilibrium method, however, are not so high as to condemn the method.

All of this shows clearly that the abridged equilibrium method is practically identical with the A.P.H.A. method as far as the determination of carbonate in boiler waters is concerned, also that the A.P.H.A. method, used in obtaining data for the embrittlement studies, gave results which agree with the actual value with sufficient accuracy as far as the carbonate content was concerned.

Hydrate Determination

Hydrate determination by the A.P.H.A. method has already been outlined. The Winkler method involves a modification of the method used by the A.P.H.A. in that if the carbonate in a mixture of hydrate and carbonate is removed, the remaining hydrate may be titrated directly. Thus, if barium chloride is added to a carbonate and hydrate solution, the barium carbonate being very insoluble will precipitate out, leaving the hydroxide in solution. Barium carbonate does not hydrolyze in solution to any appreciable extent; consequently, if a hydrate and carbonate solution containing an excess of barium chloride is titrated, only the hydrate will react if the titration is stopped at the end point of phenolphthalein. This method has been tested very thoroughly by Professor John Johnston of Yale, and is also a standard used in the alkali industry for determining hydrate in the presence of carbonate.

The abridged equilibrium method determines the hydrate by determining the pH value and calculating the hydroxide from the equation,

$$\text{pH} = \frac{\log \text{OH p.p.m.}}{17} + 11$$

In order to check the actual hydrate determinations resulting from the use of the A.P.H.A., the Winkler and the abridged equilibrium methods, the four synthetic solutions and four boiler waters already used for carbonate were tested by these methods and the results obtained are given in Table III. These show that for the synthetic solutions having a composition similar to boiler water the hydrate determined by the Winkler and the A.P.H.A. methods shows excellent agreement with the actual hydrate, while the abridged equilibrium shows practically no agreement. In the boiler waters there is no way of saying absolutely what the real hydrate content is; however, since the A.P.H.A. and the Winkler

methods show such good agreement in the synthetic solutions and also show similar results in the boiler waters, it is reasonable to assume that both are sufficiently accurate for practical purposes. Again, in the boiler waters there is no agreement of the abridged equilibrium method with either of the others, and therefore there is no justification of assuming these values to be correct.

If a study is made of the derivation of the equation for determining the OH content from the pH value, it is at once evident that the results should be in great error. It is assumed that the activity coefficient of the solution is equal to 1. In practically all of the solutions referred to this value is between 0.83 and 0.50. With

TABLE III. AVERAGE NaOH CONTENT DETERMINED IN P.P.M.

Sample Number	NaOH actually present	A.P.H.A. Method	Winkler Method	Abridged Equilib. Method	% Error A.P.H.A.	% Error Winkler	% Error Equilib.
1	94	97	96	89	3.2	2.1	-5.3
2	316	310	309	226	1.9	-2.0	-28.4
3	593	594	584	425	-1.1	0.0	-29.0
4	1575	1605	1595	1128	1.9	1.2	-28.0
108		1492	1472	1665			
109		1797	1695	1010			
110		969	939	588			
111		573	556	310			

such an assumption, the results would not be expected to be correct. Furthermore, since the hydrate content is a log function of the pH value any error in determining this value will introduce a large error in the resulting hydrate content. Thus, an error of 0.1 in the pH value means an error of approximately 25 per cent in the hydrate content. Anyone who reads any of the standard text books on determining pH values is immediately impressed with the fact that this is a very intangible value which depends a great deal on what method of determination is used by the operators; however, if the method of determining the pH is assumed to be accurate, the fact that the activity coefficient has to be assumed as equal to 1 still leaves the method very inaccurate.

Results which have been presented certainly should indicate that the A.P.H.A. and the Winkler methods give a measure of the hydrate and carbonate content of the average boiler waters tested in the embrittlement research to warrant the conclusions which were drawn, and at the same time show that the authors of this work do recognize that "the applied test methods for determining the so-called 'soda' alkalinity permit the correct interpretations of the alkaline conditions of the boiler water" for the type they were discussing and that there is no justification of the statement that "much of the field data on the alkalinity of boiler water tested in connection with embrittled boilers must be disregarded if the pH value of the water was not determined."

There are a great number of different types of boiler water and no one method of analysis is suitable for all. Thus, it has been shown that the Winkler and A.P.H.A. methods give good results for hydrate and carbonate contents in solutions free from phosphate having appreciable hydrate and carbonate contents and low organic content. Many boiler waters do not fall under this classification, however.

When a water contains soluble phosphate, the A.P.H.A. method is not supposed to be used without correcting for phosphate but the phosphate correction is rather easily calculated and made. Thus, if a solution containing carbonate, hydrate, and phosphate is titrated using phenolphthalein and methyl orange indicators, the amount of acid used to titrate to the phenolphthalein end point titrates all of the hydrate, one-half of the carbonate, and one-third of the phosphate (if pH is above 12; otherwise, less than one-third of the PO_4). The amount of acid used between the phenolphthalein end point and the methyl orange end points is a measure of one-half the carbonate and one-third of the phosphate. If the phosphate is known, the carbonate and hydrate may be readily calculated. This calculation for carbonate is:

$$CO_3 \text{ p.p.m.} = 12\,(M - P) - 0.63\,PO_4 \text{ p.p.m.}$$

when M = total amount of acid to titrate to methyl orange end point, P = total amount of acid to titrate to phenolphthalein end point. 100 c.c. of solution is titrated with 0.02 N acid. Since the inflection points occur where they do, Brom-Cresol Green and Thymol Blue could also be used.

Calculation for carbonate using the abridged equilibrium method and the same amount of solution and the same strength acid becomes:

$$CO_3 \text{ p.p.m.} = 12.36\,(V_2 - V_1) - 0.812 - 0.626\,PO_4 \text{ p.p.m.}$$

It may be readily seen that these two equations should give almost identical results with the differences being of the magnitude similar to the experimental error. In

TABLE IV. AVERAGE Na_2CO_3 CONTENT DETERMINED IN P.P.M.

Sample Number	PO_4 Present	By Evolution	A.P.H.A. Method	Abridged Equilib. Method	% Error A.P.H.A.	% Error Equilib.
1A	71	89	86	91	-3.4	2.2
2A	95	115	121	120	6.2	4.3
3A	356	320	323	321	1.0	0.3
4A	356	1568	1543	1603	-1.6	2.2
101	40	16	28	27	75.	69.
104	90	30	44	41	46.	37.
107	60	24	68	68	183.	183.

this equation $V_2 - V_1$ is the acid required to change the pH value from 8.5 to 5.0.

In order to justify this statement further, tests were run on four synthetic solutions similar to those already used for hydrate and carbonate except phosphate was also added. Three boiler waters having phosphate present were also analyzed. The results of the tests for carbonate are given in Table IV. In the synthetic solutions the carbonate content determined by both methods gave good agreement with the actual value. Thus, the determination of carbonate with phosphate present as made by the abridged equilibrium method gave results which agree with those determined by the A.P.H.A. when corrected for phosphate.

Unfortunately the samples of boiler water which contain free phosphate in the majority of cases have low alkalinity and low carbonate content. The samples of boiler water which were analyzed were of this type and had the sodium carbonate content less than 50 p.p.m. In this range all the titration methods are open to large error. The carbonate as determined by the abridged equilibrium method agrees almost perfectly with that obtained by the corrected A.P.H.A. method; however, they both gave high results, ranging from 37 per cent to 183 per cent too high in carbonate content. In solutions of such low concentrations large errors do not influence conditions of operation as much as they would in higher concentrations.

Accuracy of the hydrate content in waters having

phosphate present was also studied. The A.P.H.A. method should give a fair measure of the hydrate without knowing the phosphate content; however, in solutions with a pH below 11 or 12 there might be a tendency for the hydrate to be low. The Winkler method should give good results. The abridged equilibrium method would still be open to the errors already discussed. In order to obtain practical results, the same solutions tested for carbonate in the presence of phosphates were tested for hydrate by the various methods. The results are tabulated in Table V. The results obtained on the synthetic solutions showed that the A.P.H.A. and the Winkler methods gave good results on the average. The only high error was on solution 1A, when the Winkler gave results 17 per cent high, but this was only 16 p.p.m. in error. The equilibrium method gave results ranging from 10.1 per cent to 35 per cent in error.

Methods all agreed fairly well on the hydrate content of the boiler waters. This might be expected with hydrate contents low and in the presence of phosphates since the phosphate appears to correct the error in the abridged equilibrium method. If correction were made for the activity coefficient, however, this method would be in great error again.

Phosphates and Silicates Present

In order to determine still further the possible errors in the several methods of analyses, the synthetic solutions had silicate added and were analyzed again. The results are given in Tables VI and VII. These show that the abridged equilibrium method and the A.P.H.A. method give fairly reliable results for carbonate. The hydroxide determinations showed that the A.P.H.A. and Winkler methods gave reliable results, while the abridged equilibrium method showed wide variations again.

Conclusions to be reached from the results of the tests run with phosphates being added and with phosphates and silicates both present would be that the A.P.H.A. method corrected for phosphate and the Winkler method give reliable results when the carbonate is over about 80 p.p.m. and the hydrate above 100 and in the absence of much organic matter. The carbonate determined by the abridged equilibrium method corrected for phosphate gave results similar to those obtained by the A.P.H.A. corrected method. The abridged equilibrium method for hydrate gave inconsistent results.

In order to obtain figures as to the accuracy of the several methods when organic matter was present, four boiler waters having appreciable organic matter present were analyzed and the results are given in Table VIII. These results indicate that in this type of solution with low carbonate and hydrate content and with the organic matter relatively high the sodium carbonate determined by all methods has quite high errors. The end points of the titrations are obscure and hard to detect.

Hydrate content determined by the Winkler method should give the most reliable hydrate content in the presence of organic matter. The A.P.H.A. method is open to error because the methyl orange end point is high, thus giving low hydrate. The phenolphthalein end point should not be influenced by organic matter. Since the phenolphthalein end point is not influenced to any marked extent by the presence of organic matter, a modified Winkler method has been used for determining hydrate and carbonate content of the water. One sample is titrated to the phenolphthalein end point and a second sample is treated with an excess of barium chloride and then titrated to the phenolphthalein end point. The first titration gives a measure of all the hydrate, one-half of the carbonate and one-third of the phosphate, while the second titration gives a measure of the hydrate. Thus, if the phosphate is known, the carbonate can be calculated.

TABLE V. AVERAGE NaOH CONTENT DETERMINED IN P.P.M.

Sample Number	PO_4 Present	NaOH actually present	A.P.H.A. Method	Winkler Method	Abridged Equilib. Method	% Error A.P.H.A.	% Error Winkler	% Error Equilib.
1A	71	94	96	110	127	2.1	17.0	35.0
2A	95	314	305	321	282	-2.9	2.2	-10.1
3A	356	598	596	619	588	-0.3	3.5	-1.6
4A	356	1575	1581	1622	1600	0.4	3.0	1.6
101	40		24	39	39			
104	90		345	361	350			
107	60		157	185	127			

TABLE VI. AVERAGE Na_2CO_3 CONTENT IN P.P.M. WITH PO_4 AND SiO_2 PRESENT

Sample Number	PO_4 Present	SiO_2 Present	Na_2CO_3 by Evolution	A.P.H.A. Method	Abridged Equilib. Method	% Error A.P.H.A.	% Error Equilib.
1B	71	30	99	86	96	-13.	3.0
2B	95	117	121	126	129	4.1	6.6
3B	356	181	338	327	349	-2.9	2.9
4B	356	233	1568	1505	1592	-4.0	1.5

TABLE VII. AVERAGE NaOH CONTENT IN P.P.M. WITH PO_4 AND SiO_2 PRESENT

Sample Number	PO_4 Present	SiO_2 Present	NaOH actually present	A.P.H.A. Method	Winkler Method	Abridged Equilib. Method	% Error A.P.H.A.	% Error Winkler	% Error Equilib.
1B	71	30	102	106	115	113	3.0	13.	11.0
2B	95	117	352	348	352	400	-1.1	0.0	29.0
3B	356	181	655	657	648	517	0.3	-1.1	-21.0
4B	356	231	1654	1685	1593	1600	1.9	-3.6	3.3

TABLE VIII. AVERAGE NaOH AND CARBONATE IN P.P.M. IN BOILER WATERS HAVING ORGANIC MATTER PRESENT

Sample Number	Organic Matter	Color	Na_2CO_3 by Evolution	Na_2CO_3 by A.P.H.A.	Na_2CO_3 by Abridged Equilib.	NaOH by A.P.H.A.	NaOH by Winkler	NaOH by Equilib.
106	761	Straw	29	237	155	23	91	25
107	93	Yellow	24	68	68	157	185	127
112	29	Light yellow	25	40	42	15	30	0
113	363	Black coffee	130	383	308	338	472	210

Comparison of Inhibiting Ratio Formulas

Much discussion has evolved in regard to the proper ratio for the prevention of embrittlement and of late quite a few have felt that the A.S.M.E. ratios are in need of modification. When one studies the ratio and applies it to waters of which a thorough knowledge of composition is available, however, the number of plants which are handicapped by meeting this ratio is relatively small; however, in Bulletin No. 216 of the Engineering Experiment Station, we have outlined a modification of the older code recommendations. The graph gives the recommended ratios in detail.

In Bulletin No. 155 published in 1926, we pointed out the possibility of using the ratio $\frac{Na_2SO_4 + Na_2CO_3}{NaOH}$ for those plants having difficulty in meeting the A.S.M.E. Code recommendations.

Reference has also been made to the use of phosphate to prevent embrittlement; however, the phosphate,

TABLE IX. OPERATING CHARACTERISTICS OF THE PLANTS FROM WHICH CONCENTRATES WERE OBTAINED

Sample Number	Steam pressure lbs. per sq. in.	% Make-up	Chemicals Added to Boiler Water	Pre-treatment
101	700	2	Na_3PO_4	Evaporated
102	700	2		Zeolite
103	700	2	Na_2SO_4	Evaporated
104	250	5	Na_3PO_4	Zeolite
105	160	10		Lime and H_2SO_4 [1]
106	225	20	Organic compound	
107	400	10	Na_3PO_4	Zeolite
108	250	90		None [1]
109	160	90	None	None [1]
110	160	20	None	Lime, alum and zeolite
111	160	20	None	Zeolite
112	160	Electric	Boiler	
113	160	30	None	Zeolite

[1] Well water containing sodium carbonate used.

TABLE XI. COMPARISON OF INHIBITING RATIOS FOR WATERS OF COMPOSITION SHOWN IN TABLE X

Sample No.	102	105	106	104	108	103	107	109	110	111	101	112	113
Boiler Pressure	700	160	225	250	250	700	400	160	160	160	700	160	160
A.S.M.E. Recom. Ratio	3	2	2	3	3	3	3	2	2	2	3	2	2
A. $\frac{Na_2SO_4}{Total\ Alkalinity}$													
1. A.P.H.A. Data	7.75	9.35	18.8	0.52	0.08	1.85	1.55	0.49	1.35	1.03	0.26	0.30	0.10
2. Winkler Data	8.20	10.00	28.5	0.80	0.08	1.94	2.17	0.48	1.31	1.02	0.55	0.45	0.13
3. Equilib. Data	5.68	10.75	21.0	0.77	0.08	1.58	2.26	0.52	1.75	1.33	0.36	0.43	0.14
B. $\frac{Na_2SO_4 + Na_2CO_3}{NaOH}$													
1. A.P.H.A. Data	17.80	16.40	230.	0.89	0.48	4.85	3.85	6.35	3.48	5.25	2.42	3.06	1.84
2. Winkler Data	16.10	15.90	55.6	1.06	0.50	3.52	2.68	6.68	3.67	3.60	0.85	0.80	1.73
3. Equilib. Data	9.13	17.60	80.8	1.22	0.45	3.85	4.75	10.60	5.75	6.15	1.41		1.86
C. 1. $\frac{Na_2CO_3}{NaOH}$													
a. Evol. of CO_2 + Winkler OH	0.11	0.13	0.32	0.09	0.33	0.10	0.13	3.94	0.69	0.89	0.41	0.83	0.27
b. A.P.H.A. Data	0.88	0.42	10.30	0.15	0.34	0.85	0.43	3.82	0.73	0.94	1.17	2.66	1.13
c. Winkler Data	0.54	0.25	0.60	0.01	0.36	0.29	0.00	3.92	0.84	1.10	0.09	0.00	0.00
d. Equilib. Data	0.23	0.28	2.48	0.12	0.32	0.68	0.54	7.10	1.25	1.90	0.69		1.46
2. $\frac{Na_2SO_4}{NaOH}$													
a. A.P.H.A. Data	17.10	16.00	218.0	1.13	0.14	3.6	3.40	2.50	2.74	2.15	1.25	1.80	0.25
b. Winkler Data	15.50	15.60	55.5	1.07	0.14	3.23	2.90	2.65	2.83	2.21	0.77	0.80	0.18
c. Equilib. Data	8.90	17.30	78.5	1.10	0.13	3.17	4.20	4.05	4.53	3.96	0.77		0.39

when so used, is independent of the sulphate content, and ratios of carbonate, sulphate or hydroxide are not necessary.

In order to clarify the various ratios, how they are calculated and the effect of various methods of analysis, 13 boiler waters have been analyzed. The operating characteristics of the plants from which the samples were obtained are given in Table IX. The results of the analyses are given in Table X. In Table XI the various ratios are calculated. Boiler waters No. 102, 105, and 106 would be classed as nonembrittling according to all methods of analysis and methods of calculating the ratio. Boiler waters No. 104 and 108 are classed as embrittling by all methods of analysis and methods of calculating the ratio. Boiler waters No. 103, 107, 109, and 110 do not meet the A.S.M.E. recommendation but would be classed as nonembrittling when calculated so as to take advantage of the undecomposed carbonate. All methods of analysis give these classifications. Water No. 101 is embrittling by all methods except those recognizing the undecomposed carbonate as an inhibitant and then only when calculated from the A.P.H.A. and equilibrium data. Since this plant is phosphate treating to prevent embrittlement, however, it is not essential to calculate the ratios. Also, the carbonate alkalinity is low and all titration methods give too high an error for constant results. Water No. 112 gives similar results to those obtained in No. 101 except that there is no phosphate in this water; however, no attempt is made to maintain the ratio here because the hydrate alkalinity is so decidedly low. In water No. 113 similar results were obtained. The only time the water could be classed as nonembrittling was when the carbonate was figured as an inhibitant and then only when calculated from the A.P.H.A. and equilibrium data. If solutions 101, 112 and 113 are considered using the data from the Winkler method they would be classed as embrittling in nature, as they are when the Na_2CO_3 is determined by CO_2 evolution.

TABLE X. COMPOSITION OF BOILER WATERS IN P.P.M.

	Na_2CO_3				NaOH			Na_2SO_4	NaCl	SiO_2	PO_4	Organic
Sample Number	CO_2 Evolution	A.P.H.A. Method	Modified Winkler Method	Abridged Equilib. Method	A.P.H.A. Method	Winkler Method	Abridged Equilib. Method					
101	16	28	3	27	24	39	39	30	0	12	40	Low
102	0	56	41	29	46	73	127	1130	190	19	0	Low
103	5	20	14	33	43	48	49	155	10	5	0	Low
104	30	44	5	41	343	361	350	397	30	35	90	Low
105	28	61	49	50	194	199	179	5100	125	16	0	Low
106	89	237	55	155	23	91	64	5030	692	23	0	761
107	24	68	0	58	157	186	127	535	50	108	60	93
108	493	506	236	539	1468	1472	1665	210	82	63	0	Low
109	6475	6865	7105	7215	1797	1696	1010	4500	2143	262	0	Low
110	648	706	786	732	989	939	588	2660	956	77	0	Low
111	495	538	591	587	573	556	510	1530	395	75	0	Low
112	25	40	0	42	15	30	0	18	16	9	0	29
113	150	365	0	306	356	472	210	83	16	46	0	365

It is interesting to note that the data collected by the use of the abridged equilibrium method did not change the classification of a single boiler water to a different class than those calculated from the data collected by the A.P.H.A. method. The figures show that the data which have been collected on alkalinity of boiler waters tested in connection with embrittled boilers are very reliable.

Based upon these results, it appears that the following procedure may be recommended in determining whether or not a boiler water is embrittling:

First, determine the A.S.M.E. ratio, using the A.P.H.A. method to determine the total alkalinity. If the results obtained show that the boiler water meets the recommended ratio, no further study is necessary.

Second, if the water does not meet the recommended ratio, determine the total alkalinity by the modified Winkler method previously outlined and recalculate the ratio using the results obtained for the total alkalinity and if the ratio is high enough, no further treatment is necessary. The difference would undoubtedly be caused by the methyl orange in the A.P.H.A. reading being high due to organic, and in turn the total alkalinity would be high, making the ratio low; however, the organic matter would not influence the Winkler titrations to any marked extent and thus give a higher and more accurate ratio.

Third, if the ratio is still low, determine the ratio of the $\frac{Na_2CO_3}{NaOH}$ and $\frac{Na_2SO_4}{NaOH}$ from the data obtained from the Winkler titrations and see if these ratios, when plotted according to Fig. 1, fall above or below the curve. If the point falls decidedly above the curve, the water is nonembrittling in nature. If the point falls on or slightly above the curve, it might be well to determine the carbonate more accurately as by CO_2 evolution; however, a point falling close to the curve should be classed as embrittling in order to be safe.

Fourth, if the water is classified as embrittling in nature, then the water treatment should be changed so as to make the boiler water of a nonembrittling type.

It has been assumed that the boiler water did not contain any free phosphate; however, if phosphate is present and is being maintained at all times in the desired amount, the water might be classed as nonembrittling in nature, due to the fact that phosphate is classed as an inhibitor of embrittlement.

Turbine Expansion Lines of Actual Machines

Expansion line of utmost importance in heat balance and power development studies. Typical industrial and central station data serves for preliminary studies.

WHEN STEAM is expanded in an ideal turbine, the expansion line is vertical (at constant entropy) on a Mollier Chart. In a real turbine only part of the ideal heat drop is converted into mechanical work and the expansion line slopes to the right, the exact slope depending upon the efficiency of the turbine which, among other things, is influenced by the moisture content of the steam[1]. The ratio of the actual heat drop (converted into mechanical work) to the adiabatic heat drop is known as the Rankine (Cycle) Ratio of the turbine[2].

Before the days of the extraction cycle, the turbine water rate was sufficient to give the necessary data for heat balance studies. Since the widespread, almost universal, acceptance of the extraction turbine for both industrial and central station service, additional data regarding the condition of the steam at various points between the throttle and condenser is a necessity for heat balance calculations. Approximation of these data from the water rate and pressure conditions is possible, but water rates vary between wide limits and the expansion line will vary likewise. For definite and final studies accurate turbine data can be obtained from manufacturers, for preliminary studies data from other turbine installations are of service.

Expansion Lines

Data of this kind have been collected and plotted on Fig. 1 in two general groups, industrials in Fig. 1A and central stations in Fig. 1B. It must be remembered that these turbines were designed for many different conditions, over a wide pressure, temperature and back pressure range and that many times, especially in industrial plants, turbine design and efficiency was intended to meet certain predetermined industrial conditions.

Steepness of the expansion line indicates relative efficiencies but not in a way that would warrant direct comparison between machines without taking the many other factors into consideration. Some of the turbines were designed for extraction, some for no extraction, some for gas reheat; some are for back pressure operation, some for condensing service; some of the data are for full load, some for the most efficient load and some for intermediate conditions; some are for actual test, some from designers' figures and some from published data. Some of these important auxiliary data are given in the accompanying table listing the machine rating, load, steam flow, throttle conditions and extraction pressures and quantities. The appearance of 100 per cent in the last column indicates back pressure operation. Most of these machines are in well known stations where operating and design conditions are somewhat familiar to the industry and on which published data are available.

A variety of turbine types and sizes, including single expansion, tandem compound, cross compound, steeple compound, ranging from 1500 to 208,000 kw., are represented. Some of them deserve particular attention, among them the 1000 deg. F. (British Thompson-Houston) turbine for Delray; the 50,000-kw. Allis-Chalmers turbine at Waukegan for which actual test data were available and giving probably the most accurate and dependable expansion line of the machines represented; the Benson boiler data representing the ultimate in pressure conditions as applied to industrial applications, and the Brown Boveri Hellgate turbine, designed, to comply with steam conditions of earlier sections of the station, for comparatively low pressure and temperature, yet with a Rankine Ratio of about 87 per cent. This design data was supplied by the manufacturer on a Mollier chart drawn to metric scale and which differed in some respects from the present chart to which it was transferred by means of conversion factors so that it may not be directly comparable with other machines. Test data shows a water rate (with steam and load corrected to 265 lb. 611 deg. F.) of 10.03 lb. per net kw-hr. at a net load of 60,832 kw. This, based on the expansion line above would give an overall efficiency of about 77.3 per cent which with a Rankine Ratio of 87.1 per cent for the turbine would give the reasonable efficiency of 88.8 with the balance of 11.2 per cent covering radiation, bearing, generator and exciter losses.

Effect of Size and Pressure

Because of the smaller blading and minimum practical clearance, efficiencies of turbines tend to decrease with smaller sizes[3] and higher pressures. Early tests on the first 1200-lb. Lakeside turbine[4] show efficiencies of 80 per cent which was later materially improved by reducing the interstage leakage[5]. This was a 7000-kw. constant back pressure unit so that similar efficiencies might be expected for practically any desired industrial conditions[6].

Tests[7] made by Escher-Wyss show that the efficiency of the turbine is independent of the initial pressure if the adiabatic heat drop and turbine speed remain constant. Results of these tests are shown graphically in Fig. 2. These tests results were calculated from Sto-

[1] Power Plant Engineering, Eliminating Moisture from Turbines, page 970, Oct. 1, 1931.
[2] Turbine Studies from the Mollier Diagram, page 1095, Nov. 15.
[3] Power Plant Engineering, Efficiencies of High-Pressure Steam Turbines, page 1111, Oct. 15, 1929.
[4] Power Plant Engineering, 1200-lb. Turbine Shows 80 Per Cent Efficiency, page 1186, Nov. 15, 1927.
[5] N.E.L.A. Proceedings, page 1160, 1928.
[6] Power Plant Engineering, Turbines for High-Pressure Industrial Plants, page 804, July 15, 1930.
[7] Escher-Wyss News, page 100, July, 1930.

dola's tables which it is reported give efficiencies about 3 per cent below those of the Mollier chart current at that time. Throttling tests at high pressure carried on simultaneously checked Stodola's table.

Initial pressures were varied over a range of from 285 to 1420 lb. per sq. in., with the back pressure varied to give about the normal heat drop of the turbine. Seat-

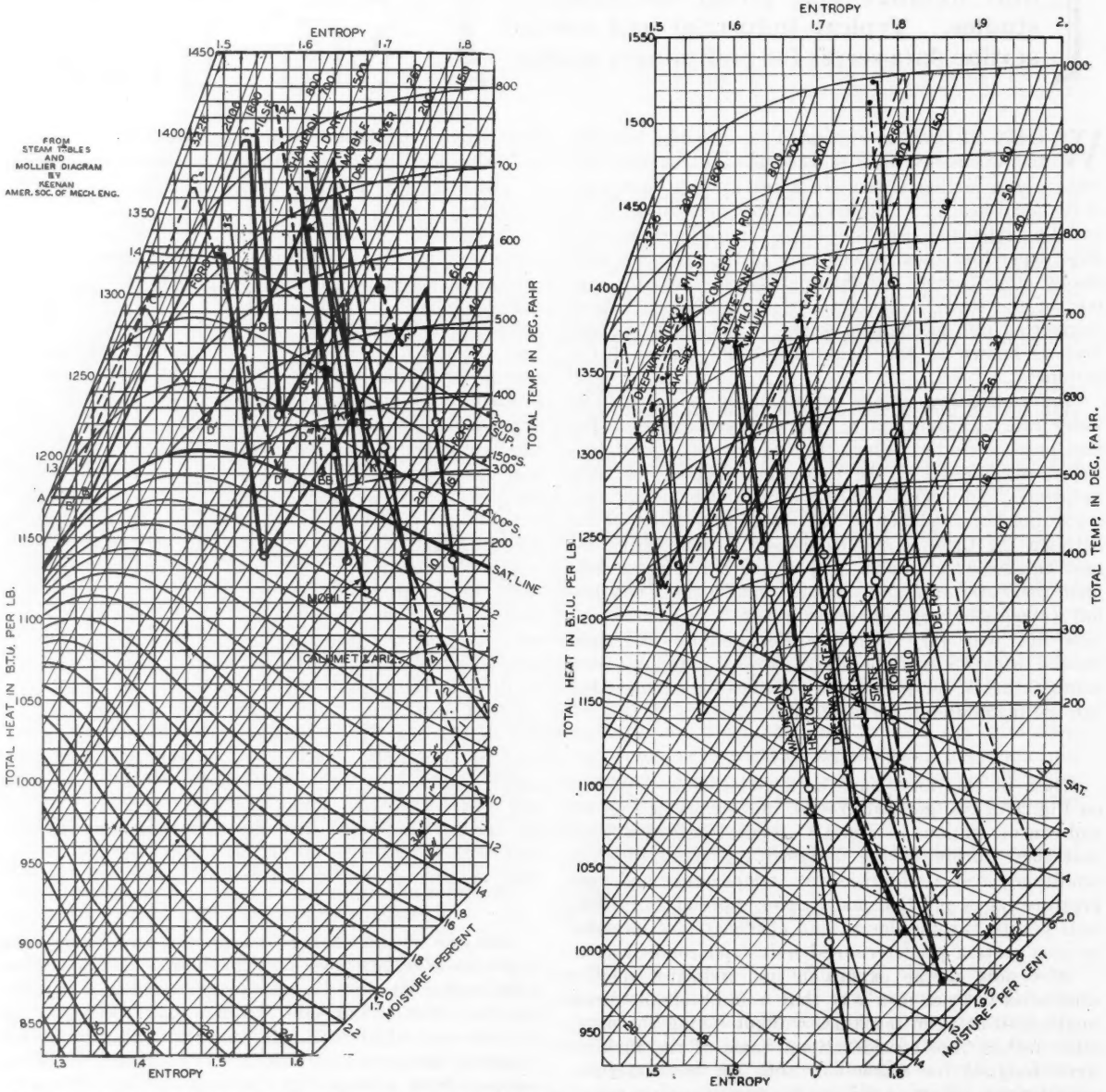


FIG. 1. EXPANSION LINES OF SEVERAL WELL KNOWN (A) INDUSTRIAL AND (B) CENTRAL STATION TURBINES

tering of the points was caused by corrosion of the nickel-steel blading brought about by salt deposits carried over in the feedwater. Corrosion had not proceeded far when the first tests showing an efficiency of 64 per cent were made. The efficiency gradually dropped to about 58 per cent as corrosion proceeded and it is estimated that the efficiency of the turbine without salt deposits or corrosion would have been about 68 per cent. From this value must be deducted gear and gland losses so that an efficiency of about 61 per cent should be expected at the coupling. These tests may at first glance seem low but if compared with a condensing turbine operating at 170 lb. initial pressure and consuming the same quantity of steam, the output would be only about 26 hp. An efficiency of 64 per cent for such a turbine would be considered very good indeed.

The turbine tested was the first 1400-lb. turbine purchased for the Siemens-Schuckert experimental Benson boiler. The exhaust was reheated at 200 lb. and used in the regular condensing turbines. Operating conditions proposed and published[8] at that time were as outlined on Fig. 1A. Water was pumped to the boiler and heated beyond the critical point[9] to the pressure and a temperature of about 750 deg. F. as at A., this steam was then throttled to about 1600 lb. at B and

[8]N.E.L.A. Proceedings, page 1262, 1928.
[9]Power Plant Engineering, Steam Generation at Critical Pressure, page 718, July 1, 1928.

heated in the superheater to about 850 deg. F. as at C. It was then expanded to D, reheated to E and expanded to F.

When the next Benson boiler, using pulverized coal, was installed, the steam reached the turbine at about 2550 lb. instead of 1400 lb.[10] and the superheat was carried only to about 790 deg. F. as at C′. Although theoretically the steam was throttled as from A to B′ and then superheated from B′ to C′ the natural pressure drop through the superheater at full load was sufficient to cause the expansion to take place along the line A C′, but at partial load the steam was throttled through a reducing valve.

Steam was expanded in the high-pressure turbine from C′ to D′ down to a pressure of 500 lb., reheated to E and expanded in the low-pressure element to F′. Steam was bled at 140 lb. for an evaporator. The course of the expansion lines C′ D′ and E F′ was dictated by industrial considerations and the guaranteed efficiency of the high-pressure turbine was only 50 per cent. Steam from both the high-pressure and low-pressure exhausts (D′ and F′) were used in process work demanding a minimum temperature of 465 deg. F. which quite definitely fixed the allowable turbine efficiencies.

When the next Benson boiler was installed[11], the initial temperature was increased to 860 deg. F. as at C″, reheat abandoned and the turbine rebladed for a steam flow of 77,000 lb. per hr. and a back pressure of 140 lb. Salt deposits had caused difficulty with the second as well as the first turbine and in the revised arrangement the high pressure turbine exhausted to an industrial evaporator[12] so that the Benson boiler would have closed feedwater system. A turbine efficiency of 50 per cent would give an expansion line from C″ to D‴. Expansion from C″ to the saturation line at 140 lb. as at D″ represents a turbine efficiency of about 66 per cent. Another German plant that warrants close study by American Industrial plants is the Ilse plant[13] operating with a boiler pressure of about 1700 lb.

Industrial Plants

In American industrial plants Champion, Waldorf and Mobile, representing units of from 1500 to 20,000 kw., may be looked upon as the utmost in careful and balanced design. For the Waldorf plant the line HK represents the 1500-kw. d.c. unit and HK′ the 2000-kw. a.c. unit. The Champion unit is in reality a 20,000-kw. triple element condensing turbine but as the low pressure element serves only as a balancing unit and receives little steam, only the two high-pressure elements are represented. The Calumet & Arizona machine is intended to show condensing operations. As the Devil's River machine rated at 7500 kw. might well represent industrial needs, it has been included in the industrial rather than central station plants. The Lakeside 1200-lb. turbine rated at 7700 kw. and exhausting at constant back pressure is also applicable to industrial conditions and has been included to complete that pressure range.

Central Station units are grouped in three pressure ranges: low pressure represented by Hell Gate (No. 8), Cahokia (No. 1) and Delray; medium pressure represented by Waukegan (No. 4), Philo and State Line (No. 1), and high pressure represented by Lakeside, Deepwater (Tex.) and Concepcion Road. The Ford turbine has also been included in the Central Station list because it is of central station proportions and represents a somewhat different steam reheat condition.

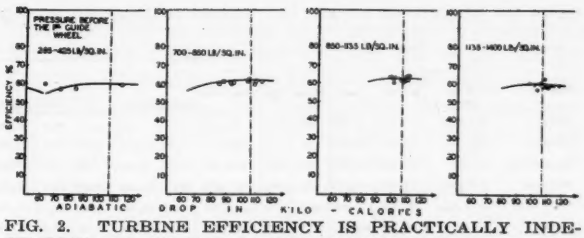


FIG. 2. TURBINE EFFICIENCY IS PRACTICALLY INDEPENDENT OF INITIAL STEAM PRESSURE IF THE HEAT DROP IS KEPT CONSTANT

Lakeside is a gas reheat station operating with constant exhaust pressure on the high-pressure machine. Two 7700-kw. high-pressure units ordinarily exhaust to one 60,000-kw. low-pressure turbine. The expansion line as drawn is for full load on the high-pressure and 50,000 kw. on the low-pressure units.

Concepcion Road has one stage of steam reheat, expanding along RS, reheating along ST and expanding from T to condenser pressure of 2 in. Because of the many low-pressure expansion lines the expansion from T downward is not shown. Ford also uses one stage of steam reheat as shown but expands to about 85 lb. reheat pressure and locates the reheater at the turbine.

Deepwater (Tex.) uses two stages of steam reheat to a total temperature of 710 deg. F. entering the low-pressure turbine. Steam leaving the boiler, at point U, passes first through a thoroughfare heater and is then split, part going to the throttle and part to a dead-end heater. After expansion in the turbines to W, the exhaust passes first through the dead-end heater where it is heated to condition Y, then to the thoroughfare heater where it is heated to Z before being expanded to condenser pressure along ZV. The high-pressure turbine is superimposed on low-pressure machines and the system receives some steam from low-pressure boilers so that the data does not represent actual operating loads.

The three medium-pressure stations offer an interesting study representing as they do Waukegan, a straight expansion, State Line, steam reheat, and Philo, a gas reheat station from approximately the same pressure and temperature conditions. In both cases reheat adds about 60 B.t.u. per lb. of steam (about 15 per cent) to the power output for a reheat input of 147 B.t.u. for gas reheat and 100 B.t.u. for steam. Because of the reheat higher temperature with gas the moisture content of the exhaust is much reduced, a factor of importance.

As for several other stations, data given for Cahokia does not represent true operation conditions in the station inasmuch as steam is extracted from this turbine to heat condensate from an older turbine in the station. Extraction data given is for heating only the condensate of this one turbine. The full line represents conditions with extraction and the dotted line near the lower portion represents conditions with no extraction. A comparison of Cahokia wih Delray gives an indication of the effect of increased temperature. They use practically the same pressure but the increase of 265 deg. F. gives an increased extraction of about 93 B.t.u. per lb. of steam (approximately 25 per cent).

[10]Power Plant Engineering, Exacting Demands of Industrial Heat Balance, page 532, May 1, 1929.
[11]Power Plant Engineering, Recent Developments of the Benson Boiler, page 612, June 1, 1930.
[12]Power Plant Engineering, Benson Boiler Five-Stage Evaporators, page 791, Aug. 1, 1931.
[13]Power Plant Engineering, 1700-lb. Plant of Novel Design, page 1058, Nov. 1, 1931.

DATA ON TURBINES OF FIG. 1. THOSE INDICATED BY * DO NOT SHOW ACTUAL OPERATING CONDITIONS (SEE TEXT)

							EXTRACTION																					
Station	Turbine type	Rating	Load	Press	Temp	Steam Flow	1			2			3			4			5			6			Total	
							Press	Pounds	%	Press	Pounds	%	Press	Pounds	%	Press	Pounds	%	Press	Pounds	%	Press	Pounds	%	Pounds	%
Delray	Tan.Comp	10,000	10,000	380	1000	81,240	8.9	3,641	4.47	34.7	4,948	6.08	120.8	6,652	8.19										15,241	18.74
Cahokia*	Sim. Exp	75,000	55,885	300	725	545,000	5.95	34,000	6.24	66.8	39,350	7.21													73,350	13.45
Hellgate #8	X Comp	180,000	60,000	280	612	600,000	1.04	9,000	1.36	10.	50,000	7.70													59,000	9.08
Waukegan	Tan.Comp	50,000	41,650	600	725	390,500	4.	21,850	5.95	13.	19,000	4.87	37.5	21,180	5.41	95.	18,780	4.81	170			325			80,810	20.67
State Line	Trip.Exp.	208,000	150,000	665	730	1,334,400	5.89	59,000	4.42	30.33	96,000	7.20	73	73,000	5.47	140.	67,300	5.04	231	60,800	4.56				356,100	26.69
Philo	X Comp	165,000	165,000	615	725	1,387,700	6.15	76,200	5.50	22.7	38,400	2.77	60	53,500	3.86	136.	119,700	8.63							287,700	20.76
Reopster*	X Comp		65,800	1310	715	565,500	9.4	29,500	5.03	47.	36,350	6.19	186	53,600	9.15										119,350	20.36
Lakeside*	X Comp	75,000	66,000	1235	750	502,320	4.1	22,645	4.51	12.	20,203	4.02	43	34,524	6.87	101.6	30,074	5.98							107,466	21.38
Concepcion	X Comp		15,000	1235	600	148,000	10.	11,470	7.85	84.8	12,650	8.67	10	9,680											33,780	23.15
Ford	Vert.Comp	110,000	111,870	1215	725	997,450	8.8	58,800	5.90	31.5	30,850	3.10	65.5	84,500	8.47	320.	115,200	11.56							289,350	29.03
Ilse*	Tan.Comp	12,000	12,000	1435	648	188,800	207.	89,000	47.3	50	99,000	52.7													188,000	100.
Waldorf	1 Cyl.D.C.	1500 kw	1500	665	750	41,130	90.	41,130	100																41,130	100.
Waldorf	1 Cyl.A.C.	2000	2000	665	750	47,800	55.	47,800	100																47,800	100.
Champion*	X Comp	185,750	17,980	615	725	301,340	177.	30,650	10.18	79.8	21,290	7.07	30	249,400	82.75										301,340	100.
Siemens-Sch.	Tan.Comp			2550	790	55,000	510.	4,400	8.0	148.	26,400	46.0	78	24,200	46.0										55,000	100.
Mobile	1 Cyl.	6,000	6,000	490	675		155.			50.			19													100.

The dotted line at the top of the Philo low-pressure element represents the heat drop in the high-pressure element, showing that the increased temperature of the Delray unit is of more value from the heat extraction standpoint than is the reheat equipment plus the additional 225 lb. pressure. It is for this reason that the 1000 deg. F. experiments at Delray are being watched.

Pressures and Temperatures

The Mollier chart also clearly shows the reason for the statement often made that the central station is interested primarily in higher temperatures and the industrial plant in higher pressures. The central station is interested only in the power generated and although superheat shows little theoretical advantage, practice proves that moisture[1] seriously reduces turbine efficiency and increases maintenance. Practical considerations call for the expansion line as far to the right of the Mollier chart as possible.

On the other hand, the industrial plant is interested primarily in back pressure operation with the exhaust conditions quite definitely fixed by industrial conditions. As a rule, high superheat in the exhaust is not desirable for industrial use but a low superheat of 10 to 20 deg. (point BB) is often preferable to wet steam. Assume steam at 85 lb., 20 deg. F. superheat is desired and the electrical and steam loads show they would balance at a water rate of 25.3 lb. per kw. or (with 90 per cent mechanical and electrical efficiency) a heat extraction of 150 B.t.u. per pound of steam.

With a turbine expansion line along AA-BB the initial pressure conditions would be fixed at about 580 lb. 690 deg. F. If less power were needed, a lower pressure and temperature could be used. Increasing the temperature only, would throw the expansion line to the right, increase the superheat in the exhaust and give no increase in power. If more power is needed, a further increase (along the line AA-BB) in both pressure and temperature is needed and for the range of usual industrial process steam requirements, this increase gets into the unexplored pressure region as quick as, if not more quickly than it does into the unknown temperature region. If wet steam is permissible, the expansion line is thrown to the left and this also means an increase in pressure. European Benson and Loeffler plants successfully operating, cover this higher pressure range up to 2500 lb. 850 deg. F.

Of course, successful application of 1000 deg. steam at low pressure does not indicate that reheat is to pass out of the picture. Benson boiler installations already successful for operation from point C″ may be applied to central station practice expanding for instance from C″ down to the saturation point at about 300 lb., reheat to 1000 deg. and expand down to I.″

Diesel Engines as Peak Load Units

Costs of Diesel Stations of 500 to 1000 hp. Capacity with Special Reference to Peak-Load Service in Outlying Communities Rather than in Main Central Stations. By S. A. Hadley*

CERTAIN characteristics of the Diesel engine, such as absence of standby losses, the ability to start quickly with no preliminary expense and its operation after being started with minimum attention, have always been recognized as favoring its use to carry intermittent loads, including peak loads in central stations. Other characteristics, such as the limited capacity of single units and the cost of installation, have been unfavorable factors for such use. The characteristics first mentioned remain unchanged, along with its inherent high efficiency, which is practically the same for all sizes.

Economic pressure has forced the development of larger sized units and of more compact designs operating at higher speeds which have decreased not only the first cost of the unit but the cost of generators attached to them and of buildings to house them. Thus the field open to their use in intermittent service, particularly peak-load service, has been greatly widened.

As an example of the cost of stations during the World War and the period of expansion following, the cost of a 1500-hp. station in two units made for an industrial concern in Kansas is given. For this period the influence of the World War conditions increased the price of this station from $145.75 per kw., for which it might have been built in 1914, up to $187 per kw.

As an example of present prices there might be adduced a 1200-hp. two-unit municipal plant for which

*McIntosh & Seymour Corp., Kansas City, Mo. Abstract of a paper delivered before the A.S.M.E.

bids were received in November, 1930. The plant was to be complete, including building, foundations, fuel storage and handling, cooling-water equipment with softener, all piping, switchboard and wiring and accessories. The accepted bid made the cost, including an engineering fee of 5 per cent, substantially $110 per kw., which was not very far from the average of all bids submitted.

Advantages of Diesels for Peak-Load Service

The author believes that more study should be made of the possibilities for reducing the cost of current when

TABLE I. COST OF INSTALLATION OF 500-KW. DIESEL PEAK-LOAD STATION UNIT

750-hp. modern-type Diesel unit, with lubricating system complete, fuel day tank, heater and strainer, exhaust muffler, tools, spare parts and anchor bolts, freight and services of an erecting man.	$40,000.00
500-kw. generator and exciter delivered with engine.	4,500.00
Switchboard control panel, with automatic voltage regulator and connecting cables and conduit	1,300.00
Piping for fuel, lubrication, starting air, cooling water and exhaust	600.00
Fuel storage, 30,000 ga. with transfer pump.	850.00
Labor for unloading, cleaning and assembling equipment ready for operation.	800.00
Cooling tower, with basin and cooling-water pumps.	950.00
Building of plain brick construction, fireproof, with glazed interior wall surface, including both building and machinery foundations, also I-beam with chain hoist and trolley over center line of unit.	4,500.00
Plans, engineering and general supervision of construction	4,000.00
TOTAL INSTALLATION COST.	$53,600.00
Interest during construction	550.00
GRAND TOTAL.	$54,150.00

distributed to the point of use by the employment of Diesel engines of moderate capacity, that is, from 300 hp. to 2000 hp., installed in suitably located outlying sub-stations and operated regularly over peak-load periods. In this way they would serve the double purpose of peak-load equipment and standby or emergency equipment. Installation costs would be reasonably low, even though the station capacity is relatively small, because such installations would most invariably consist of single units which permit the lowest installed cost per kw. capacity. Their operating costs would be low, because they would be run only with a fairly good load and would have low attendance charges, as will be explained. For such plants the operating periods would vary much in different localities, but in general they would probably be run daytimes in the summer and during the winter from about 7 a.m. until 9 a.m. and from about 4 p.m. until 10 p.m.

In a community of moderate size, say from 1500 to 2500 population in the Middle West, served by a transmission line from a large central station, one employe would usually be maintained to look after the distribution systems and substation equipment and this employe could, with little extra cost, be one capable of starting and stopping a Diesel engine for these daily runs, so that the labor charge for the generation of this peak-load current would be practically nothing. In larger communities supplied under the same general system and requiring a larger Diesel installation for their emergency and peak-load needs, conditions would still permit the operation of the Diesel plant with small additional labor expense. There is usually a storehouse and shop as well as a substation and if combined with the Diesel-engine station, this will help to reduce attendance and overhead charges.

The field contemplated in this paper is the typical Middle Western community of from 1000 to 5000 population without any large manufacturing or industrial load, having a general use of from 400 to 500 kw-hr. annually per inhabitant and served by an interconnected transmission system. In these systems the cost of base-load current, including fixed charges of the generating equipment, is about 1 cent per kw-hr. The cost of transmission lines to sub-stations of outlying communities will average about $3000 a mile, including substations and the losses, including transformer at each end, will approximate 25 per cent.

Engineering Results from Peak-Load Diesels

Addition of Diesel engines to sub-stations in outlying communities for carrying peak loads as well as for emergency and standby service would give these results:

The transmission system, including transformers, could be smaller and cheaper than for serving the communities without the Diesel-engine peak-load station. The main central-station plant could be smaller and could be designed as a true base-load station, thus giving the utmost efficiency possible.

For each outlying Diesel peak-load station with, say, a single 500-kw. unit, the central-station-plant capacity could be decreased 625 kw., but it might not be deemed desirable and safe to cut off this capacity entirely. It would be reasonable, however, to allow some reduction

TABLE II. PRODUCTION COST FOR PLANT SHOWN IN TABLE I, NOT INCLUDING FIXED CHARGES, MANAGEMENT EXPENSE OR LOCAL DISTRIBUTION

	Kw.-hr.
100 summer days, 12 hr. average 200 kw.	240,000
100 spring and fall days, 8 hr. average 250 kw.	200,000
100 winter days, 6 hr. average 300 kw.	288,000
Assumed yearly output	728,000
Fuel rate at average load, 0.45 lb.per b.hp.-hr.	
Generator efficiency, 92.5%	
Weight of fuel per gal., 7.5 lb.	
Miscellaneous losses, 5%	
Fuel, 66,400 gal. at 4½¢.	$2,985.00
Lubrication for 2960 engine hours, 22,000 rated 740 gal. at average of 60¢.	445.00
Maintenance and upkeep of the unit, taken at $1.50 per hp. per yr. in view of service conditions.	1,125.00
Waste, grease and miscellaneous supplies.	150.00
Attendance, half time of one man for 3500 hr. per yr.	1,050.00
Total production cost, not including fixed charges, management expense or local distribution.	$5,755.00

in both central-station capacity and line capacity on account of this outlying peak-load station. It might reasonably be expected that there would be a reduction of 400 kw. in station capacity amounting to $32,000 and a reduction of 400 kv-a. in line capacity amounting on a 30-mi., 33,000-v. line, including transformers, to about $8,000.00.

The cost of installation of a 500-kw. Diesel peak-load station will be approximately as shown in Table I.

For this intermittent service, it is not necessary to have quite the same auxiliaries as would be installed in a base-load plant. Production cost for such a Diesel peak-load station will be as in Table II.

Effect on Main Station

Other advantages are worth considering. If this idea is fully carried out, the main station becomes a purely base-load station, with its efficiency greatly improved and the liability of outages greatly decreased,

both of the station and the transmission system, due to the absence of daily peaks which are usually carried on part of the overload capacity of the system. The line and transformer losses are cut down considerably, and their reliability is also increased, for the same reasons. The customers in the community where the Diesel peak-load station is situated obtain better-maintained voltage and greatly reduced interruptions to service and also there is a feeling of much greater satisfaction, due to their knowledge that they have a plant running in their own community. Even though the plant is shut down every day during light-load periods, its presence, with its daily operation, creates a good feeling that seldom exists in a community served entirely from a distance.

The size of the Diesel peak-load station and its daily operating period should be fixed only after consideration of several factors, namely, the low, average and

TABLE III. ESTIMATED ANNUAL COST OF DELIVERED ENERGY. CITY, 5000 POP.; 30 MI. FROM STEAM STATION; PEAK 900 KV.A., 775 KW., 2,650,000 KW-HR. A YR. OIL ENGINE 500 KW. CARRYING 475-KW. BASE LOAD

Assumption	1	2	3
Schedule of	Oil Engine	Oil Engine	All on Transmission
Relative KWH on Engine	20%	40%	
KWH delivered	2,650,000	2,650,000	2,650,000
KWH by engine	530,000	1,060,000	0
KWH delivered by line	2,120,000	1,590,000	2,650,000
KWH delivered to line 15% losses	2,500,000	1,870,000	3,120,000
Investment			
Transformers	$6,975	$6,975	$10,500
Line	60,000	60,000	90,000
Engine	55,000	55,000	
Total Investment	121,975	121,975	100,500
Annual Cost			
Fixed Charges	15% $18,296	15% $18,296	14% $14,070
Transmitted Energy (1.0¢)	25,000	18,700	31,200
Fuel & Lubrication (0.5¢)	2,650	5,300	
Maintenance	1,500 (oil eng.)	1,800(oil eng.)	400(Line)*
Labor	1,200	2,400	
Misc. Supplies	150	150	
Total	$48,796	$46,646	$45,670
Cost/KWH Delv'd.	1.84¢	1.76¢	1.72¢
Additional cr. for improved load factor on steam station **	2,500	1,870	
Total	46,296	44,776	45,670
Cost/KWH Delv'd.	1.75¢	1.69¢	1.72¢

*Additional maintenance due to additional circuit.
**Including released steam station capacity after considering diversity.
Note: In practice, a transmission line would serve several such loads, hence this problem is hypothetical in nature.

peak loads of the community served and their relation to the capacity of the main central station when operating as a base-load plant, the length and efficiency of the transmission line connecting them, the probability of increased load in the vicinity of the peak-load station and the location of this peak-load station, as to whether it is on a single line or interconnected through a loop or ring system with other similar peak-load stations within reasonable distance.

Further Discussion of Factors to Be Considered by Public Utilities

B. J. George, Industrial Engineer, Kansas City Power & Light Co., discussing this paper, said that use of Diesel engines by privately owned utilities at the end of transmission lines constitutes the real scope for the application of Diesel engine units for peak-load and standby service. It is Mr. George's opinion that in the long run the public utilities will be even better customers of the oil engine manufacturers than at present. The public utility with its competent staff of operating and maintenance men, thoroughly trained in the generation and distribution of power, is best equipped to maintain and operate a Diesel engine plant properly, where the economies of the situation justify the installation. The decreased cost of installation of Diesel engines, the increasing capacity of units and the tendency toward higher speeds will increase the advisability of the public utility giving serious consideration to the use of oil engine units particularly in their installation as peak load and reserve units in small communities which are beginning to show development in electrical load. Where transportation, fuel and water conditions at the base station are unfavorable, this is even more advisable.

As Mr. Hadley points out, however, the question is one for analysis in each individual case. The final results will depend greatly upon local conditions, such as prices of material, labor, fuel and certainly the important question of the future development of the territory. It seems to Mr. George that the public utilities should continue to give the subject open-minded consideration from the following viewpoint.

In territories in which electric service is not available from transmission lines and in which the present revenue does not justify the extension of transmission lines to the territory, the utility might find it economical to install oil engine units of the size to take care of the immediate future developments; then as the territory develops, supplement the oil engine units with transmission lines, allowing the oil engine to take the peak load and to act as a standby unit. Later, as the community develops to justify the installation of a two-circuit transmission line, the oil engine can be used as reserve capacity or removed from service and installed in another community where the need is greater. The oil engine with its inherent advantages of readiness to serve, its low standby expense and its portability is particularly adapted to this plan of development.

Table III embodies the result of an analysis for a city of approximately 5000 population served by a transmission line 30 mi. long.

It will be noted that the first total of annual cost does not make any allowance for the increased efficiency of the steam station when operated as a base load station, nor does it make any allowance for the released capacity in the steam station.

On the whole, the results of the table indicate the truthfulness of the statement that each individual case is one for consideration. It also clearly illustrates how the assumptions made can easily vary the final results from one conclusion to the opposite. An inspection of the figures will show that a variation of a mill or so in the cost of power delivered to the transmission system will vitally affect the final results.

The statement of Mr. Hadley with regard to the cheapening of Diesel engines when used as peak and standby units is interesting. Of course, the same statements will apply to steam stations when built for standby service. The question of the effect upon public relations, company policy, and the possibilities of the future development of the territory must not be overlooked in the analysis of the problem. In the long run these things will be the more or less final determining factors.

PARALLEL OPERATION OF A. C. GENERATORS

By E. H. STIVENDER

Part II.* In the first part of this article the author discussed the characteristics of induction and synchronous generators and the effects of these characteristics upon parallel operation. In this part he continues with a consideration of the use of current-limiting reactors, as related to parallel operation.

IN SOME GENERATING plants, the use of current limiting reactors when paralleling is a part of the regular operating procedure. When the proper external reactance is placed between two machines being synchronized, insurance against the flow of destructive currents in case of improper switching operation is provided.

Owing to the fact that iron core reactors of the proper design would be of excessive cost, size and weight, reactors for this service are usually of the air-core type. The reactance of this class of apparatus is comparatively low; it affects the voltage regulation only slightly at normal loads, for instance, a reactance of 2 per cent in the generator leads will cause a drop of 2 per cent in voltage at normal full load and will limit the short circuit currents to 50 times normal full load current. This voltage drop being at 90 deg. to phase voltage during normal loads, affects the circuit only slightly except when abnormal currents flow. Of course, in the case of a generator, these currents being of a low lagging power factor nature tend to lower the generator voltage considerably so that the short circuit current, after the first instantaneous rise, can never reach 50 times normal.

It is often the case that reactors are placed in circuit only during times that machines are being paralleled, short-circuiting switches being provided which shunt them out after all synchronizing and paralleling has been completed. In this manner, the benefit of safety during paralleling, offered by reactance in the circuit, is obtained, while abnormal currents occurring during general operation are controlled by protective relays. The added synchronizing power offered by reactance in the circuit between two machines is sometimes taken advantage of. This is infrequently the case, however, since modern machines are correctly designed with respect to synchronous reactance so that adequate synchronizing power is provided without the aid of external equipment.

The effect of additional reactance in the external circuit is illustrated in Figs. 1 and 2. In Fig. 1(a) generators represented by voltages E_1 and E_2 were paralleled differing in phase by the angle a. In the circuits of generators 1 and 2 the inductive reactance equals the resistance, hence the exchange current will lag behind the resultant voltage E_R by an angle of 45 deg. The synchronizing power varies with the value of the exchange currents, the cosine of the angle between I and E_2, and the value of E_R. The current is equal to E_R divided by the impedance of the complete circuit including that of other machines in parallel, hence the impedance being constant the synchronizing power varies with the cosine of the angle between I and E_2, and the square of E_R. This power tends to turn E_2 and E_1 to the positions shown in Fig. 1(b), where with equal values of E_1 and E_2 the resultant E_R will be zero, hence no exchange currents will flow.

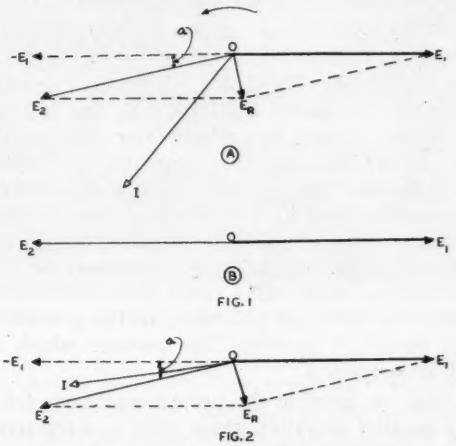


FIG. 1

FIG. 2

FIGS. 1 AND 2. ILLUSTRATING THE RELATIONS BETWEEN SYNCHRONIZING CURRENT I AND TWO GENERATOR VOLTAGES E_1 AND E_2

Fig. 1 is where the resistance drop of the complete circuit is equal to the reactance drop, and Fig. 2 is where the resistance drop is negligible

In Fig. 2 the reactance of the closed circuit is large compared to the resistance, causing the exchange currents I to lag nearly 90 deg. behind E_R and come more nearly in phase with E_2, thereby making the cosine of angle E_2OI greater than in Fig. 1(a) with the same value of E_R; hence the synchronizing power is greatest when the ratio of reactance to resistance is greatest. Of course the presence of too great a value of reactance is detrimental to synchronizing power; it is possible to limit the exchange currents so as to reduce this power after a certain value of reactance has been reached. Nearly always, in modern generators, the effect of what little resistance is in the generator circuit may be ignored entirely for ordinary calculations of synchronizing power.

An interesting fact brought out in the diagrams of Figs. 1 and 2 is that the generator whose voltage is ad-

*Part I appeared on page 1023, October 15, 1931 issue.

vanced in phase (E_2) is that which delivers power; that is, since E_2 and I are to the left of the Y axis (or in the same general direction), the generator represented by voltage E_2 produces power; likewise since E_1 and I are in opposing general directions the generator represented by voltage E_1 receives power, or acts as a motor.

Other factors which indicate the illustrative power of such diagrams are that in Fig. 1(a) angle E_2OI is less than angle — E_1OI, hence power delivered by generator No. 2, or $P_2 = E_2I \cos E_2OI$, is greater than $P_1 = E_1I \cos$ — E_1OI, or the power delivered by generator No. 2 is greater than that received by generator No. 1. This is evident when considering that generator No. 2 must furnish the I^2R loss of its own windings as well as that of generator No. 1.

By observation of Fig. 2, where the resistance is negligible, angle E_2OI is almost equal to — E_1OI or: $P_2 = E_2I \cos E_2OI = P_1 = E_1I \cos$ — E_1OI; that is, power delivered by generator No. 2 is equal to that received by generator No. 1, with no I^2R loss of significant value. Therefore within certain limits, by increasing the reactance of the closed circuit, less current is required for a given synchronizing power; the I^2R loss is thereby reduced and, for small coupling angles, most of the current flowing produces synchronizing power.

Further examination indicates the effect of the angles between current and voltage on the two voltages of the circuit. In Fig. 1(a), where the current lags less than 90 deg. behind E_R, I leads E_2 and lags behind E_1; since both E_2 and E_1 are generator voltages, the exchange current I demagnetizes generator No. 1 and magnetizes generator No. 2, that is voltage E_2 is increased. E_1 is decreased but by a greater amount because the phase angle is nearer 90 deg. As the position in Fig. 1(b) is approached, this effect decreases and the voltages become their original value again when synchronism is reached. The effect of resistance in the synchronizing current circuit is to cause the machine which is advanced to compound.

In order to provide the proper conditions for satisfactory parallel operation, there must be a reactive drop in voltage of at least 6 per cent when the generator is carrying its full load current. Most generators are designed for more than this value of reactance. In many cases, a special connection of voltage regulators is provided in order to produce this drooping characteristic artificially; that is, an increase in the lagging current of a generator will automatically bring about a drop in generated voltage and a decrease or reversal of magnetizing current raises the generated voltage by action of the regulator.

Currents and phase angles shown in Figs. 1 and 2 exist only during a short interval after paralleling, when the speed of the prime movers is accurately governed. If poor speed regulation exists, or if the throttle of one machine is opened more after paralleling, exchange currents will flow in the manner described above and one machine becomes a motor if the external load is not sufficiently great to prevent such action.

When closing the line switch under improper conditions, thereby causing the flow of excessive currents, if the switch is equipped with overload relays these currents may be of sufficient value to cause opening of the switch by relay action. Under extreme conditions where the switch may be closed when a phase angle of 180 deg. exists, immediate re-opening may cause a voltage of twice normal across a pair of circuit breaker contacts. This is evident from the fact that mechanical imperfections prevent all three poles from opening at precisely the same instant, hence explosions of circuit breakers may occur from the resulting currents of improper switching, when they may not occur due to circuit breakers opening under severe overloads. Of course, due to the inductance of the generator windings a sudden interruption may cause an induced voltage of many times normal also.

It is seldom the case that current limiting reactors are placed directly in the generator leads, or in the main supply leads to the bus, because it is undesirable that a short circuit or heavy overload on one outgoing line should cause excessive voltage drop on all other lines. Also, by placing reactors between sections of the bus or in individual outgoing lines, their current carrying capacity may be selected for a lower value, hence affording greater current limiting protection.

University of Illinois Issues Data on Humidity for Comfort

In view of the extended interest which has recently developed concerning humidification for residences, the demand for some single source of information, easily available, has become urgent. The object in the preparation of Bulletin No. 230 of the Engineering Experiment Station of the University of Illinois was, therefore, to consolidate certain useful information from various sources, and to present experimental results which have been obtained by the Engineering Experiment Station incident to coöperative researches with the National Warm-Air Heating Association and with the Institute of Boiler and Radiator Manufacturers.

As a result of the study, it was found that the principles underlying humidity requirements and limitations are as follows:

Optimum comfort is the most tangible criterion for determining the air conditions within a residence.

An "effective temperature" of 65 deg. represents the optimum comfort for the majority of people. Under the conditions in the average residence, a dry-bulb temperature of 69.5 deg. F. with relative humidity of 40 per cent is the most practical for the attainment of 65 deg. "effective temperature."

Evaporation requirements to maintain relative humidity of 40 per cent in zero weather depend on the amount of air inleakage to the average residence, and vary from practically nothing to 24 gal. of water per 24 hours.

Relative humidity of 40 per cent indoors cannot be maintained in rigorous climates without excessive condensation on the windows unless tight fitting storm sash or the equivalent are installed.

The problems of humidity requirements and limitations cannot be separated from considerations of good building construction, and the latter should receive serious attention in the installation of humidifying apparatus.

Copies of Bulletin No. 230 may be obtained without charge by addressing the Engineering Experiment Station, Urbana, Illinois.

A Strenuous STEAM ENGINE Repair Job

Part IV.* High Pressure Side Overhauled; Lubrication Changed; Governor Rebuilt; Reheater Made Serviceable.

By *George H. Wallace*

WITH THE SECOND ENGINE rebuilt and in operation again, carrying an increased load, the engine on which the original repairs were made was shut down in order to rebuild the high-pressure side, which was badly in need of repair. The front cylinder head had leaked badly for some time, but after removing the cylinder, three days were consumed in removing the head. When the cylinder was off, it was decided to rebore both the barrel and the four ports on a small boring mill in the local shop, rather than with a portable bar with the cylinder in place.

This was not only a very slow and tedious job, but the mill bored the ports with considerable taper and several thousandths out of round. All new valves were purchased from the engine builder, rough turned oversize and turned and fitted on the job, lapping them in to a perfect seat.

It seems that this cylinder had been installed after the original job had been on its present foundation, and in the readjustment, together with the addition of another piston at a later date, the clearance was very slight. It required frequent adjustments of the piston rod in the crosshead to compensate for takeup on the connecting rod bearings.

To overcome this, the cylinder heads were machined enough to provide proper clearance, according to measurement, and when all was reassembled, a clearance of 3/16 in. was obtained. This was considered ample and the valves were set accordingly.

Valve stems were turned down and built up electrically on the packing site; the T heads built up and remachined; and the keyways filled in and new ones laid out in order to give the proper valve lap, with the proper layout of the valve levers. New metallic packing was then made, as described for the other stems.

Lubrication Changed

As the old pins of the valve gear had been worn from 0.010 to 0.040 in., out of round, all new pins were made and the brass keyheads reamed or bushed as required. A new hand cutoff device was made for the low-pressure side.

The throttle valve, being of the double opposed balanced geared type, had to be completely rebuilt and the seats reground. It was also remodeled as to lubrication, the oil inlet being changed from under the valve, to a point over the valve, to permit better vaporization.

—*See Part I, page 901, Sept. 1, 1931; Part II, page 980; Part III, page 1068.

When the high-pressure connecting rod was removed, it was found that the crosshead pin brasses were broken in six pieces, and at some time or other, they had seized the pin, broken off the dowel and turned the pin in the taper, cutting it badly. The crosshead was taken out to the old country boring mill, and the taper rebored. The last section of locomotive axle was used to turn a new crosshead pin, 8 5/8 in. diameter in the bearing and 32 in. long. This was ground into the taper a perfect fit, bored for oil feed, drilled for oil and dowel, and slabbed off on an old miller for clearance.

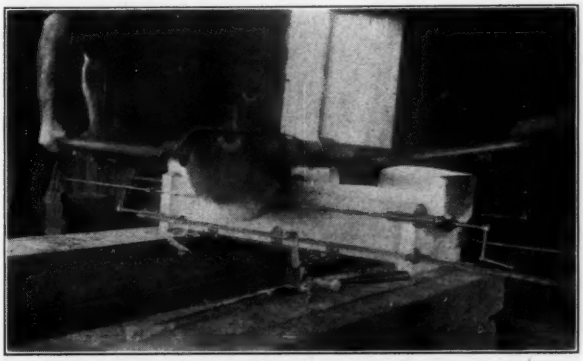


FIG. 11. POURING BABBIT ON 24 BY 42 IN. MAIN BEARING.

The connecting rod was taken to the old boring mill and the crankpin wedge hole rebored to 4 3/16 in., the same as the low-pressure side; a new wedge turned up and new 2 in. screws made. New brasses for the crosshead pin were purchased from the engine builder and scraped to a fit on the new pin.

Crosshead shoes had to be rebabbited and were whittled down on the planer (as has been described) before finishing them in the lathe. In this connection it was discovered that at some time in the past, the low pressure crosshead had been rethreaded slightly larger, probably to overcome poor threads from frequent loosening of the piston rod. At any rate, the high pressure crosshead would not fit on the low pressure mandrel, so a new thread was cut on the mandrel, one for each crosshead and marked for future reference.

While being assembled on the present site, or enroute from the former location, the governor spindle was bent but left to operate that way. When in opera-

tion, the top of the spindle described a circle of ¾ in. dia. The governor standard was rebored, and the counterpoise lapped out with a suitable mandrel, as there was no faceplate that would hold the counterpoise to rebore it. A new spindle was turned from a forging to fit the new bearings. It was reversed frequently in the lathe to prevent springing. It was then lapped into the bearings and when in operation, not only ran perfectly, but gave a vast improvement in the regulation of the engine.

Dashpot brackets were located on the side of the cylinder and the short ball-end drop rods from the double yoke connection to the drop levers, were badly worn with the years of service and required new rods. These were but 10 in. long with a 1⅛-in. thread nearly the entire length and with a 2¼-in. ball at one end. The balls were turned by swiveling the compound rest in the rear of the work and using the lathe in the reverse. With repeated trials, a uniform sphere was obtained and then turned down to size, with a variation

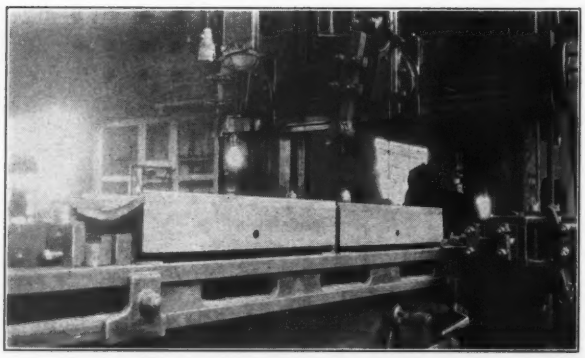


FIG. 12. PLANING THE FACES OF A SIDE SHELL BEFORE REBORING.

of not to exceed 0.001 in. A new triangular strap of bronze was cast to hold the balls into the dashpots and with a little care they were bored to fit the balls. A little grinding made the joint a perfect one.

While the engine was in operation immediately after the repairs on the low-pressure side, it was noted that there was considerable leakage in the joints of the receiver and piping due to the punishment it received at the time of the accident. It was therefore necessary to renew all the gaskets in the receiver and piping, quite a task inasmuch as the top receiver head was close to the basement ceiling.

Many Reheater Pipes Loose

Upon opening the receiver, it was found that about 30 of the 1½-in. reheated pipes had broken off and fully half of the remainder were either unscrewed entirely or loose enough to be turned by hand. To reach the pipes to work on them, it was necessary to remove a short 16-in. connection between the receiver proper and the oil separator which was located between it and the high-pressure cylinder; then to remove the pipes through the manhole near the top, about a third of the pipes must be unscrewed and set to one side to give room enough to pass them out.

All the pipes were cut off to the length of the shortest ones and rethreaded oversize. Where the pipes were broken off in the tube sheet, the stub ends were chipped out; holes retapped oversize and the pipes screwed in again with litharge and glycerine used for dope.

Since the original stay sheet at the top of the reheater pipes had been bent and damaged beyond repair in service, it was found impossible to remove the top receiver head to put in a new one and to make a new one in sections that would pass through the manhole could not be done with the tools at hand. Sections of flat steel were passed through the manhole and welded to the tops of the pipes to brace them and to cause the steam to pass among the pipes and be reheated enroute to the low-pressure cylinder.

The high-pressure piston rod packing which came with the engine, had been revamped sometime in the past, so that the several grooves for the packing rings were of different sizes. They had worn so much that when in operation previous to general repairs they leaked badly. The owner of the plant preferred to have new rings made special to fit the old casings, so a drawing was made of each, since, among other differences, there was a discrepancy of 0.015 in. in the diameter of the piston rods. In due time the new packing arrived and, to our joy, the manufacturer had made entirely new rod packing throughout according to their usual standards, the only error being that they were stamped for the wrong end of the rod.

Packing glands had been drilled to admit cylinder oil back of the first set of rings and about 45 deg. from the vertical line. They were redrilled to admit the oil on the vertical line and between the first and second sets of rings. The old two-feed cylinder oil pump was used to supply oil exclusively to the cylinder under the throttle, the old packings being oiled by an unreliable drip cup. A new four-feed oil pump was purchased and connected with tubing to each of the rod packings and the other two feeds connected together and led to the top of the throttle valve, where oil entered the steam space on a spoon spray, passing through the valve enroute to the cylinder.

Main Bearing Side Shells Rebabbited

Since the 24 by 42-in. main bearings had run a number of years, they were inspected, and the side shells found to be badly worn, and the babbit cracked. The oil channels at the edge of the lower bearing showed practically no signs of flaked or "wiped" babbit, so usual in bearings run for some time. The side shells were removed and rebabbited on a wooden mandrel covered with drawing paper. When put on the boring mill and set up, it was found that the boring bar that would carry the only cutter head which would fit that radius (12 in.) was so badly sprung and the tail bearing so badly worn, that it was necessary to make a new bar to fit the head and a new bearing to fit the bar.

Since the side shells had to be bored separately, each had to be set up in such a manner that when rebored, it would fit the shaft and also the wedge. Dummy wedges of the standard taper were laid on the bed of the boring mill, and the wedge face of the shell laid on these, and parallel with the bed. Then to locate the center of the shaft (consequently the center of the boring bar), with reference to the bottom face of the shell, a small inside micrometer was placed on the side

surface of the bottom bearing in the engine and adjusted carefully while a short blade with center head attached, was leveled perfectly above it.

The reading of the micrometer, taken at the four corners of the lower bearing was naturally the distance from the bottom of the side shell to the center of the boring bar at either end, and it was clamped and bored thus and although it required a minimum of scraping, the shells had to be handled in and out with heavy chain tackles which was a tedious task.

With everything finally in place, the engine was started and with a few adjustments was placed in service. Indicator cards showed that no changes were necessary in the original valve setting, except naturally a few adjustments of the knock-off rods. The rebuilt governor handled the engine with practically no variation in speed over a wide range of loads, and as far as operation and apparent economy were concerned the engine to all intents and purposes was as good as new. The original four days advice that stretched into 350 days of hard work, some of it in humid temperatures was at an end.

Spillway Waste Power Salvaged

PUMPED STORAGE FROM SURPLUS STREAM FLOW AT WAGGITAL, SWITZERLAND

ANNUAL OUTPUT of 110,000,000 kw-hr. and average daily output at peak of 86,000 kw-hr. are obtained from this development, which includes two stations and two reservoirs, the upper one being used for seasonal storage of run of river, also for seasonal and daily pumped storage, while the lower one receives discharge from the upper station and the lower reaches of the river, utilizes these for light loads and, from excess daily and seasonal flow, generates current to pump from the lower reservoir to the upper.

Through the foothills of the Alps, 28 mi. southeast of Zurich, the river Aa flows to Lake Zurich. About 10 mi. from its mouth are narrow gorges, two of which have been closed by dams to form reservoirs, the upper one at Innerthal, the lower at Rempen. At Innerthal, Fig. 1, a dam 363 ft. high by 515 ft. long, of triangular section, 247 ft. thick at the foundations and 178 ft. thick at the level of the gorge, forms a lake of 1.6 sq. mi. with capacity 5,203,220,000 cu. ft. It receives the drainage of 17 sq. mi., 3,060,510,000 cu. ft. a year, from this area and 1,404,940,000 cu. ft. a year from pumped storage. The annual variation in level is 165 ft. in the driest seasons when average depth of water is 117 ft.

From this reservoir, water is led through a valve chamber 10.5 ft. diam. to two intakes which deliver to a tunnel, 12 ft. diam. lined with mass concrete 8 to 20 in. thick except at the lower end where reinforcement is used. Capacity is 1160 cu. ft. a sec. at head of 180 to 218 ft. At the lower end is a surge chamber, 66 ft. diam., whence lead twin pipe lines, seen in Fig. 2, 8 ft. diam. and 1850 ft. in length to the station which is located at and discharges into the Rempen reservoir. The upper part is riveted pipe, the lower part, Mannesmann tubes 1.34 in. thick, the line being carried on roller bearings, provided with expansion joints between sections and anchored at the two points where slope changes.

Supported on a reinforced concrete mat, the Rempen steel-frame station, 173 ft. 10 in. by 85 ft. 3 in. and

FIG. 1. DAM AND UPPER RESERVOIR AT INNERTHAL
FIG. 2. POWER STATION AT REMPEN RESERVOIR AND PIPE LINE TO INNERTHAL

52 ft. 6 in. high, is equipped with four vertical Francis spiral turbines with capacity of 22,500 hp. at 858 ft. head or 15,000 hp. at 666 ft. head. These drive 3-phase alternators to give output of 19,800 or 16,500 kv-a., voltage being 9700 to 8800 v. and frequency 50 cycles

per second, transmitted on a 4-wire line to Siebnen power station.

For pumping, four units are provided driven by 6500 and 5100-hp. motors at 750 r.p.m. to deliver 328 cu. ft. per sec. each against 858 to 808 ft. head, through the pipe lines and tunnels to the Innerthal reservoir. Current for the motors is supplied from the Siebnen station, Fig. 4, during periods of low load and excess flow from the Rempen reservoir.

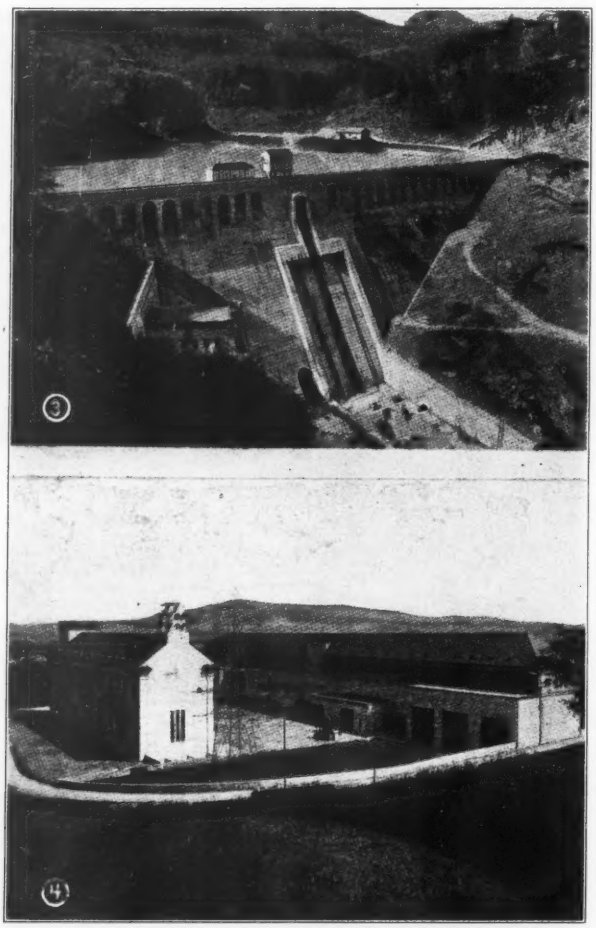


FIG. 3. REMPEN DAM WITH SPILLWAYS. REMPEN STATION IS AT THE FAR LEFT-HAND END BEHIND THE POINT
FIG. 4. PLANT AT SIEBNEN DEVELOPS POWER FROM REMPEN RESERVOIR AND FURNISHES CURRENT FROM EXCESS FLOW TO PUMP FROM REMPEN RESERVOIR FOR STORAGE AT INNERTHAL

That reservoir receives, besides the discharge from the Rempen station, the flow from the Aa river below the Innerthal dam, from the Trebsenbach river and other streams. It is formed by a dam, Fig. 3, 104 ft. high by 291 ft. long, having two spillways and an automatic overflow valve, which acts in case the reservoir level continues to rise after the spillways are carrying their full capacity. Its capacity is 14,208,000 cu. ft.

From Rempen reservoir, water is carried for the Siebnen station through a concrete-lined, 11.9-ft. tunnel, 1.6 mi. long, having a short length of reinforced-concrete pipe to cross the Trebsental river, to connection with two pipe lines 2640 ft. long. The pipes are 8.25 to 7.25 ft. diam. and 0.4 to 1 in. thick.

Siebnen plant has a station 242 ft. 9 in. by 46 ft. by 49 ft. 2 in. high and a switch house 426 ft. 6 in. by 65 ft. 7 in. by 49 ft. 2 in. high, both being of steel frames and concrete slabs, carried on reinforced-concrete mats. Generator equipment is four units, Francis vertical turbines and 3-phase generators with outputs of 16,500 to 19,800 kv-a. at 580 to 650 ft. head. Switch pedestals and panels for control of the units are located on the first floor of the station, also step-up transformers, four of 16,500 kv-a. capacity for current from the Rempen plant and two pairs of 16,500 kv-a. connected solid to the Siebnen generating units. Rempen current is stepped up to 50,000 v. and Siebnen current to 50,000 or 150,000 v. for delivery to the switch house. In an annex a third pair of 16,500 kv-a. transformers is provided for interconnection of the 50,000-v. and 150,000-v. buses when desired. The 50,000-v. equipment is arranged on three floors, the first having remote-control oil switches and one set of bus bars, the second another set of bus bars and the current transformers, the third auxiliary bus bars and potential transformers. The 150,000-v. equipment is in a one-story building at the side. Most of the output is delivered to the City of Zurich and to the Nordostschweizerische Kraftwerke A. G., who jointly own the development, but connection is also made to the Swiss national network.

For illustrations and much of the data given, we are indebted to Engineering of London, England.

From Small Beginnings

FOLLOWING THE investigations of Louis Pasteur, Robert Koch first saw the tuberculosis germ, which made possible scientific treatment of the disease. Edward L. Trudeau, a victim under treatment visualized the possibility of stamping out the White Plague by means of organization and education. Vincent Y. Bowditch concluded that treatment need not be based on climate and

altitude but was possible anywhere. Lawrence F. Flick formed the first society for fighting tuberculosis and Herman M. Biggs worked out a program for local activity which has developed into a nation-wide organization, the National Tuberculosis Association. To help meet its expenses, Christmas seals are sold and the purchase and use of these gives everybody opportunity to participate in this movement to rid humanity of one of its most destructive foes.

FURNACE HEAT release limitations imposed by pulverized fuel do not hold for stoker firing because a large part of the total heat release takes place in the fuel bed.

HEAVY PULLEYS have a flywheel effect in steadying speed but must be carefully balanced.

2500-lb. Testing Boiler

WATER LINE, CIRCULATING BOILER FOR RESEARCH ON ACCESSORY BOILER EQUIPMENT. BY D. ROBERT YARNALL

IN CONNECTION with the description of the high-pressure boiler described in Dean A. A. Potter's paper before the A.S.M.E., it will be of interest to engineers to know that another high-pressure boiler has just been installed and placed in service in our new steam laboratory in Chestnut Hill, near Philadelphia, designed to aid in developing apparatus for the power plant and for industrial plants.

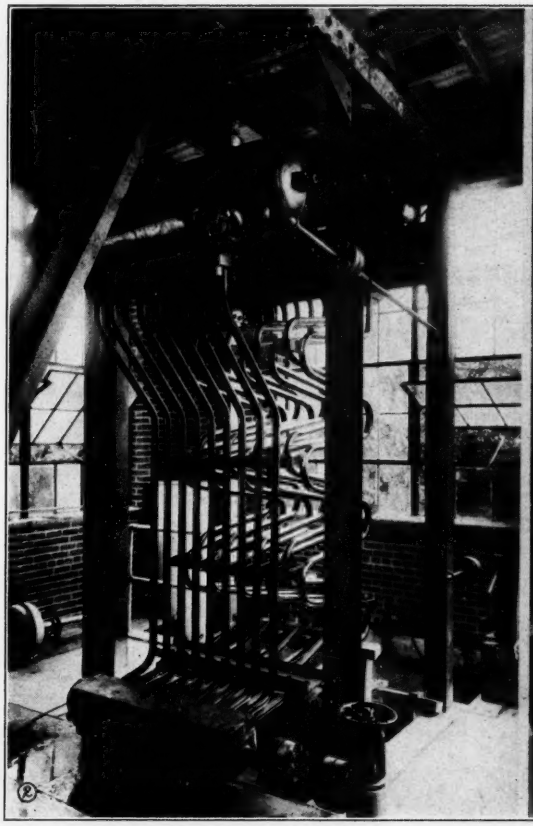


FIG. 1. BOILER ERECTED BUT WITHOUT SETTING

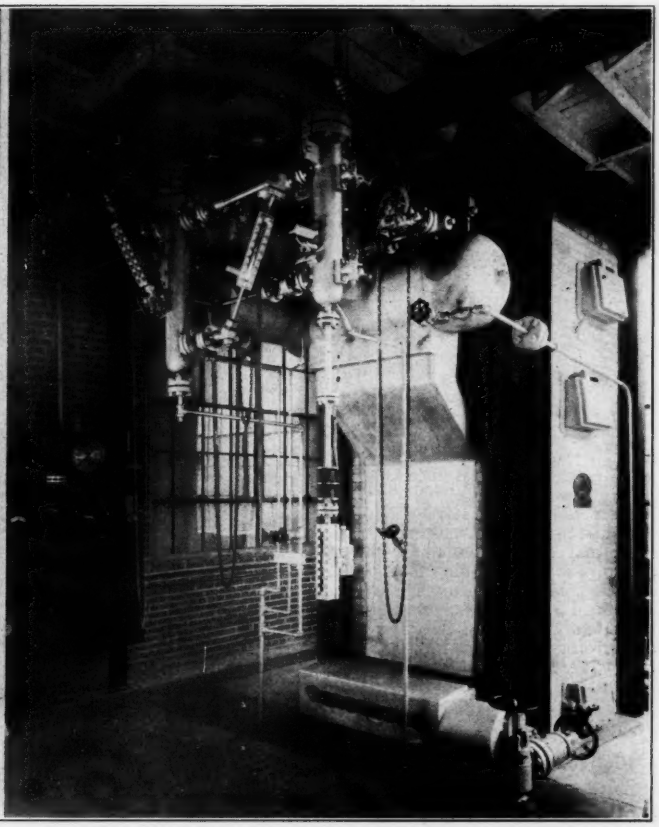


FIG. 2. BOILER, ACCESSORIES AND OPERATING PANEL

This boiler, built by the Superheater Co., is of unusual design, as will be seen in Figs. 1 and 3. To the best of our knowledge it is the only boiler built to date for 2500 lb. working steam pressure which depends only on thermal circulation for the protection of evaporating surface.

Between the mud drum and steam drum is the evaporating surface, of ascending multi-loop construction, to eliminate strain due to contraction and expansion at connections to the mud and steam drums. Down-comers are located out of the gas pass but inside of the setting so as to insure against any steam generation in them which might change the direction of flow in the evaporating surface.

At 2500 lb. pressure steam bubbles are considerably smaller than at lower pressures, therefore considerable care must be exercised in the design of a boiler for this high pressure to keep the metal temperature within its safe operating range. By the ascending multi-loop construction, the water is compelled to circulate continuously in the same direction so that those parts of the heating system exposed to the greatest heat always have water present and not until the gases have cooled down do they come in contact with the tubes containing a mixture of steam and water.

Evaporating surface is joined to the mud drum by rolled joints with hand-hole openings opposite but is joined to the steam drum by a special clamp construction with metal to metal joint, eliminating the necessity of hand-hole openings for making this joint. This cuts down the number of joints on the steam drum, which practice proves should be kept to the minimum, especially when working under such high pressures. All joints are arranged on the outside of the gas pass, accessible for inspection as well as for maintenance, at the same time making the boiler as simple as possible in construction.

The steam drum is 5 ft. 10 in. long, outside diameter 18 in. with 3 in. wall thickness. It is made from

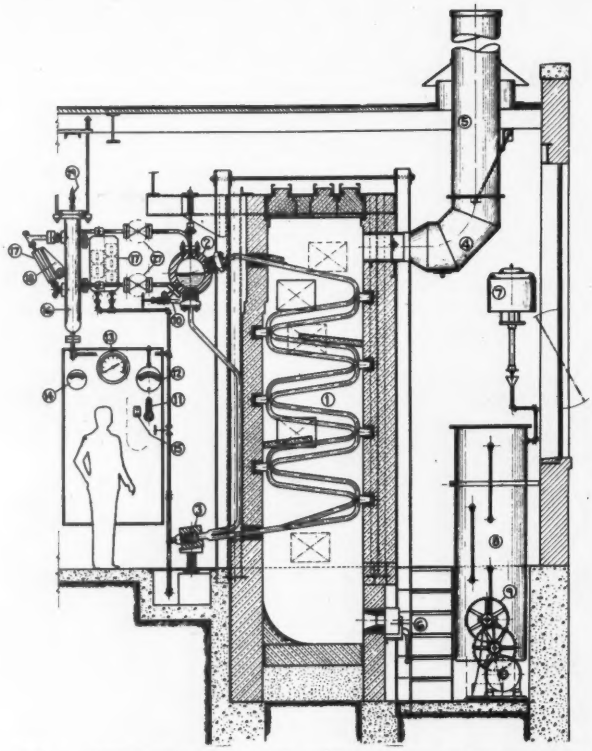


FIG. 3. SECTION OF BOILER FEEDWATER STORAGE AND PUMP, BOILER CONTROL BOARD

1. Boiler in gas pass; 2. Steam and water drum of forged steel; 3. Mud drum of forged steel; 4. Breeching, with hand operated damper; 5. Vertical stack supported from roof; 6. Automatic gas burning equipment; 7. Condensate still for boiler feed; 8. Condensate storage tank; 9. Triplex boiler feed pump with direct-connected motor; 10. Feed connection which enters steam and water drum under the water line; 11. Master clock control for time shutdown of plant in case of neglect; 12. Indicating and controlling gage for maintaining constant pressure desired during a test; 13. Steam pressure gage; 14. Remote induction-bridge-principle water level indicator; 15. Push button control for feed pump; 16. Main water column with high-low alarm; 17. Inclined high-pressure flat glass water gage; 18. New type water gage illuminator; 19. Alarm whistle.

a solid forging as for most high-pressure boilers. The mud drum is also bored from a solid forging.

Made for 2500 lb. relieving pressure, the safety valve is of the conventional type used on present high-pressure boilers but for a series of tests at lower pressures extra springs were provided for relieving pressures of 750, 1500 and 2250 lb.

Different types of forged-steel water columns, also high-pressure flat and round glass water gages, are provided as shown in Figs. 2 and 3. Blowoff valves installed for test purposes are of the forged steel seatless type, designed for high pressures.

This boiler has 130 sq. ft. of heating surface for maximum working steam pressure of 2500 lb., with a furnace volume of 82 cu. ft. It is fired by city gas, the rate of combustion being automatically controlled by the steam pressure for each test, that steam pressure being controlled by an adjustable regulator.

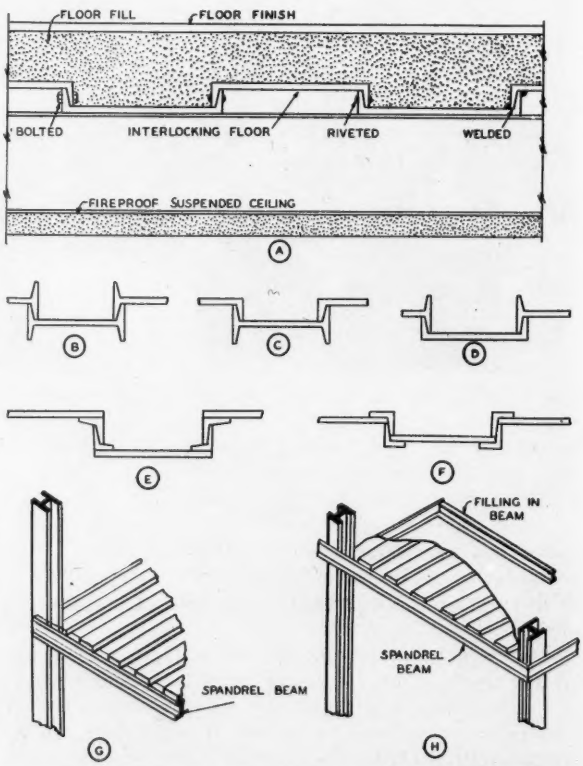
Because of the small bore of the tubes which form the heating surface, elimination of scale is important, hence an evaporator has been provided, the condensate from which is stored in a vertical tank, shown in Fig. 3, from which a triplex, motor-operated feed pump provides the necessary boiler feed.

Steel Floor of Interlocked Structural Shapes

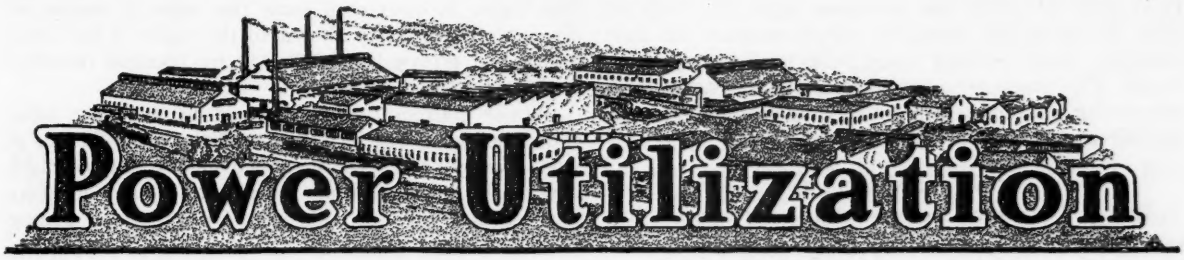
DEVELOPED by Joseph G. Shryock, chief engineer of Belmont Iron Works, this construction is adapted for fireproof construction to carry any load. It may be constructed by shop fabrication in panels or by fabrication and erection on the job. As illustrated, it may have bolted, riveted or welded joints and may utilize channels, I beams or plates and angles in any desired combination, of any weight to give the required stiffness. Space for piping and conduit is provided by the channel or I beam troughs. Fireproof floor finish can be bonded and tied to the structural floor and machinery can be either bolted down to it, or suspended from it. Advantages, such as erection along with the steel frame structure, safe storage for building material, support for winches, concrete mixers and other equipment during the construction period, are obvious.

Detailing and fabrication may be done on the job by the structural steel contractor or, for heavy loads, bridge and structural engineers can design floors to meet any requirements the same as for the steel framing.

In construction, wood forms, temporary flooring, and reinforcement for concrete are eliminated. Floor openings are readily provided and ceiling or roof finish easily attached. Also, by extending the floor over the tops of spandrel beams, rigid support may be provided at each floor for exterior walls.



VARIOUS METHODS OF INTERLOCKING STRUCTURAL STEEL SHAPES IN THE CONSTRUCTION OF FLOORS A—DETAILS OF BOLTING, RIVETING AND WELDING. B—BEAMS. C—BEAMS AND CHANNELS. D—CHANNELS AND BEAMS. E AND F—TWO ARRANGEMENTS OF PLATES AND ANGLES. G—CORNER OF TIER CONSTRUCTION. H—CORNER OF CEILING CONSTRUCTION



Water Cooling

COOLING TANKS, CENTRAL COMPRESSOR SYSTEMS.

BY L. M. JORDAN

COOLING COILS are of several types to meet the requirements in various classes of usage. One type, known as the direct-expansion, double-pipe storage type, consists of a storage tank and a double pipe coil in which one pipe is carried within the other, the refrigerant flowing through the inner pipe and the inlet water through the outer one in opposite directions. The refrigerant first flows through a coil in the storage tank then through the double pipe coil to cool the incoming water which is stored in the reservoir. An expansion valve is used with this coil that operates on a high suction pressure. It is best suited to installations where intermittent high peaks are encountered and may be used with either a circulating system, the individual cooler or a remote cooler but not in multiple hook-up.

Another type, known as the flooded, double-shell storage type, consists of a flooded tubeless evaporator equipped with radiating fins installed in a circular cooling tank containing the water to be cooled. It is designed for use with either the circulating, multiple or individual systems, has storage capacity up to 100 gal. and is therefore also suited to intermittent peak loads.

The flooded instantaneous type coil without storage consists of a water coil submerged in the refrigerant tank, the coil being so arranged that it cannot be damaged by freezing. Temperature control is automatic by a valve in the suction line that maintains constant suction pressure in the tank regardless of pressure in the vapor return line, thus making it suitable for multiple hook-up, with other equipment operating on a different suction pressure. This outfit is so small in size that it can be readily built into wall or pedestal fountains of existing equipment that are suited to multiple hook-up. It is best adapted to usage requiring a constant flow of comparatively large quantities of water and can be used in the circulating, the multiple or the individual systems. A number of these coolers may be connected in parallel by connecting each coil to a separate condensing unit, thereby considerably increasing the capacity of the plant.

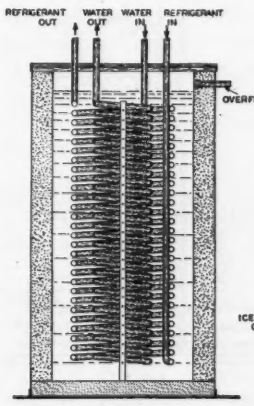


FIG. 1. COOLING TANK WITH WATER AND REFRIGERANT COILS IN SWEET WATER BATH

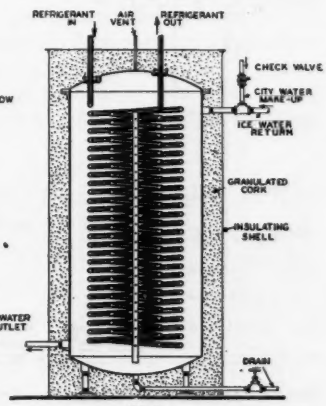


FIG. 2. REFRIGERANT COIL IN COOLED WATER STORAGE TANK

The flooded submerged evaporator in a sweet water bath is lower in efficiency due to the indirect transfer of the heat to the evaporator through the water bath. Considerable space is occupied by the cooling chamber due to the volume required by the sweet water bath. An advantage is gained, however, in that a large hold-over capacity is available in the water bath.

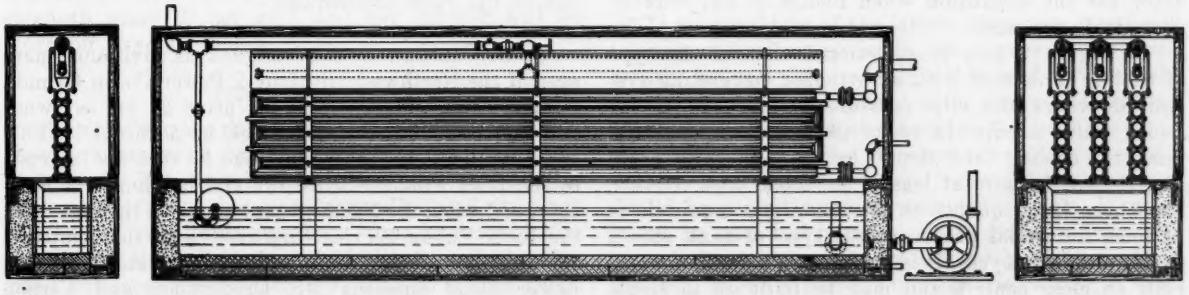


FIG. 3. SECTIONS OF BAUDELOT TYPE COOLER WITH END VIEWS OF SINGLE AND TRIPLE STAND ARRANGEMENT

This type of cooler also complies with the laws of some states which prohibit direct contact of any drinking water cooling agent with the water to be drunk. The pressure in the water coil is outward, thus preventing contamination by any harmful matter or pollution contained in the sweet water.

Cooling Tanks for Circulating Systems

In Fig. 1 is shown a cross-section view of a cooling tank designed for use with a circulating system, employing the sweet water or inert bath. In the chamber, are the usual expansion coil and another which

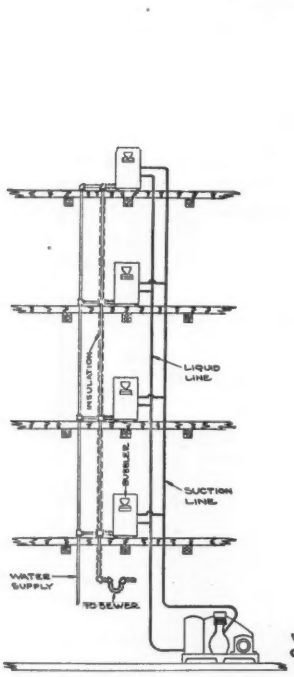


FIG. 4

FIG. 4. MULTIPLE DISTRIBUTION OF REFRIGERANT FROM ONE COMPRESSOR

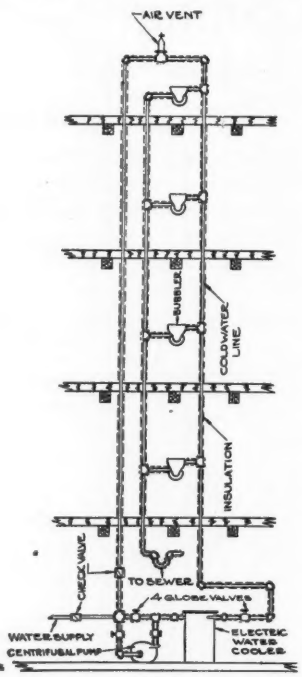


FIG. 5

FIG. 5. CIRCULATING WATER SYSTEM FROM SINGLE COOLING UNIT

serves merely to conduct the drinking water through the tank. The inert bath water can be frozen to ice, thereby storing up considerable reserve duty for bridging over rest or repair periods to the compressor. The former will prolong its life and the latter is inevitable with any machine.

It should be remembered that the freezing of inert tank water to ice can be practiced only with an open type system where the make-up water is so fed to the cooling tank that the tank is never completely filled with water, space above the water being sufficient to allow for the expansion when frozen to ice, without damage to the tank.

In Figure 2 is a cross-sectional view of the type of cooling tank used with an attic-fed circulating system or where the city pressure is allowed on the cooled water circuit. In either the open or closed systems, the cooling tank should be insulated with granulated cork lagging at least 4 in. thick.

Where large quantities of water are required, as in some industrial processes, the type of tank shown in Fig. 3 is employed. It is made up of 2-in. horizontal coils on close centers and may be built up in single or multiple stands as shown at the ends of the figure. The water is circulated over the coils by means of the centrifugal pump shown to the right of the main figure and is evenly distributed by troughs installed above the coils.

Water consumption is replaced by the float valve shown in the lower left corner of the main figure. A wood sheathing, galvanized lined on the inner surface covers the cooler on all sides, while the collecting basin is insulated on the sides with 6 in. of granulated cork and rests on 4 in. of pure cork board.

Circulation of Refrigerant or of Water

In manufacturing plants or other large buildings, circulating systems can be operated from a single centralized compressor. The multiple system can be used for ground floor or other local cooling stations within limits of the condenser pressure or lift head, as in Fig. 4. From any cooling station, water circulating lines may be laid to reach sections of the plant that are too far distant to be served by the refrigerant lines, or for heights beyond the lift head capacity of the compressor, as in Fig. 5. This simplifies the installation by using a single compressor to carry the entire load. Each water circulating system will require its individual circulating pump and control fixtures as for a complete system. As the horizontal length of the gas lines is limited only by the friction in those lines, the distributional area would be practically unlimited.

It is necessary to check the number of persons to be served by each cooler of the individual or multiple style and the class of employment to obtain the amount of cooled water that each cooler will be required to deliver; then multiply the consumption in gallons per hour by 8.3 and the product thus obtained by the temperature difference between make-up and drinking water to obtain the compressor capacity for the individual cooler. The sum of capacities for the units to be employed on the hook-up gives the rating of the single central compressor. A margin of safety should in all cases be allowed to take care of losses in the gas transmission lines but these are of minor importance as the liquid refrigerant is under condenser receiver pressure until admitted to the expansion coils and little or no losses are involved in the liquid lines. With high-efficiency expansion coils, compressor suction pressure is approached at the coil outlets, permitting but slight expansion in the vapor return lines. All horizontal vapor lines, such as the connections between the risers and the manifold and the main returns, should slope slightly toward the compressor so that any moisture occuring from back frosting of the lines will be drained from the insulation. If any traps are necessary, they should be located in the main returns and not in the riser connections.

J. B. Calderwood has resigned as divisional manager of the Northwestern Light & Power Co. in Grundy Center, Iowa, effective Oct. 26, after 22 yr. as owner and manager of the plant, which he acquired in 1909 from Walter Scott. Six years ago he sold his interests to the Iowa Public Service Co. and continued as manager, and when the Northwestern acquired the unit from the Iowa Public Service continued with the company. Recently a new $85,000 plant was put into operation. Lester Dodd succeeds Mr. Calderwood and Vernon Mooty becomes manager of the plant.

Wire Rope Use and Care

AS GENERALLY used for transmission, hoisting or haulage, round rope is made of several strands twisted around a hemp core. The hemp is used to give greater flexibility and a cushion for the outer strands but, if rope is to be exposed to intense heat as in steel mills or foundries, a steel strand is used as core, preferably of the same material as the rest of the rope.

Usually, each strand is made of a few large wires twisted together, the most common construction being 19 wires, all of one size. For greater strength and metallic contact, Warrington construction, 7 wires of one size surrounded by 12 wires, alternately large and small, increases the strength by 10 per cent and is found satisfactory for general hoisting. In the Seale construction, a large center wire is surrounded by 9 small wires, these in turn by 9 large wires but this gives a rather stiff rope hence is suitable only for conditions where flexibility is a minor consideration.

Six strands are usually twisted about the hemp core, which is saturated with lubricant, either to right or left, making right-lay or left-lay. For flexibility, short twist is used but long twist has somewhat greater strength and durability. Twist of the strands around the core is usually opposite to that of wires in the strands, known as regular lay. For resisting external wear, where drums and sheaves can be large enough to permit less flexibility, lang-lay may be used with twist of the strands around the core in the same direction as twist of the wires in the strands. This gives crossing of wires in adjacent strands at a less angle than regular lay, hence reduces the internal wear known as "nicking". Surface contact with drums and sheaves is greater so that wear is more evenly distributed but flexibility is considerably less, rope is more easily untwisted and is difficult to splice. Lang-lay rope should hardly be used except after consultation with the rope manufacturer as to its suitability for the purpose in hand.

Where great flexibility is required, special construction with flat strands having a large number of small wires laid side by side and sewed together with annealed wire may be used but this is somewhat costly and not often necessary. Flattened strands are, however, used by some manufacturers to get greater surface contact and longer wear.

For standing rigging and guys, galvanized rope is less liable to corrosion but should not be used for transmission or hoisting as the galvanizing reduces the strength some 10 per cent and the coating will be worn off anyway in use.

Rope Strength

Strength of rope depends on the material, of which three grades are in common use, iron, cast steel and plow steel. The first is ductile but of low strength, low-carbon steel being now generally used in place of iron. It is suitable for drum type elevator cables and similar uses where load is moderate and abrasion small but large drums should be used to reduce bending. Cast steel is harder than iron with about double the tensile strength and is used for mine hoists, freight elevators and the like, its lightness and flexibility giving it an advantage over iron rope to handle the same load. Where extra strength is desired, an open hearth steel is sometimes used, known as extra strong cast steel, with about 10 per cent greater strength than standard cast steel rope.

Plow steel is a still better grade of open hearth with strength 10 per cent greater than extra strong cast steel. It is also tougher and is commonly used for heavy hoisting as on cranes, derricks and dredges, also for hauling as in logging. For especially severe requirements, such as steam shovels and wrecking derricks, a special quality plow steel is made, usually under a brand name of the manufacturer.

Strength of a rope depends, of course on the number of wires, the number of strands and the size of wires, which will vary with the rope diameter. The table herewith gives working strength of standard 6-strand rope, 19 wires per strand using a factor of safety of 5 and for drums of diameters not less than those given. If smaller drums or sheaves are used, the factor of safety should be 6 to 8. For plow steel, drum and sheave diameter should be at least 24 times the rope diameter.

Working Loads and Drum Diameters for Wire Rope 6 Strands, 19 Wires

Diam. in.	Working Load t. of 2000 lb. Iron	Cast Steel	Plow Steel	Drum Diam. ft. Iron	Cast and Plow Steel
¼	0.22	0.44	0.53	1½	1
⅜	0.48	0.96	1.15	2¼	1½
½	0.78	1.68	2.00	3	2
⅝	1.20	2.50	3.10	4	2½
¾	1.70	3.50	4.60	4½	3
⅞	2.36	4.60	5.80	5½	3½
1	2.90	6.00	7.60	6	4
1¼	4.56	9.40	12.00	7½	5
1½	6.60	12.80	16.00	9	6
1¾	8.80	17.00	22.00	11	7
2	11.00	21.20	28.00	12	8
2¼	14.40	26.60	37.00	14	9
2½	18.40	34.00	46.00	15	10
2¾	22.20	42.20	55.00	17	11

Drums and Sheaves

These should be of the largest diameter practicable to reduce bending stress in the rope as such stress greatly reduces life and allowable load. Preferably, drums should be grooved, with centers of grooves spaced to give ample clearance as for instance ⅞-in. centers for ¾-in. rope. Grooves should be of radius slightly larger than the rope to avoid wedging and should be perfectly smooth to avoid cutting. Winding in two layers is bad practice. Extra cost of a long drum is more than compensated by longer life of the rope. If, however, double winding is unavoidable because of space limits, the last groove should rise spirally so as to lead

the second layer of rope above the first layer without shock.

Alinement of sheaves and drums should be such as to minimize wear on the side of grooves and on the rope. A sheave leading to a drum should be lined with the center of the drum or of that part on which rope is to be wound. The sheave should be set far enough from the drum so that the greatest angle which the rope makes when leading to the extreme turn on the drum with the line from center of sheave to center of winding space on the drum is not over 2 deg.

Sheaves should be watched carefully and renewed when much worn or when roughened, as a worn or rough sheave can quickly injure a new rope. Reverse bending over sheaves will wear rope faster than anything else and must be avoided.

When installing wire rope, if it comes coiled, the coil should be rolled like a hoop to straighten the rope out on the ground. If on a reel, the reel should be mounted on a spindle or turntable and rope pulled off straight avoiding all kinking and untwisting.

Rope should be lubricated at regular intervals with compounds of cylinder oil which will penetrate the strands and reach the inner wires but lubricant must be free of acids or alkalis which might cause rust or corrosion, thus weakening and stiffening the rope. For rope which must run under water, a coating of tar whose acid has been neutralized with fresh slaked lime is used.

End Sockets

Care must be used in attaching an end socket to make a good job but, if well done, an end socket should take a load 80 per cent that of the rope. Length of the socket basket into which the rope end fits should be 4¾ times the rope diameter and diameter of the small end of the hole should be:

for ¼ to 7/16-in. rope, rope diam. + not over 1/16 in.
for ½ to ¾-in. rope, rope diam. + not over 3/32 in.
for ⅞ to 1⅛-in. rope, rope diam. + not over ⅛ in.
for 1¼ to 1½-in. rope, rope diam. + not over 3/16 in.

Before cutting, the rope should be seized at the end and at two other points. Each seizing should be of good length, for large ropes several inches, and of annealed wire as follows: For 5/16 to ½-in. rope use No. 18 wire; for ⅝-in. rope, No. 17 wire; for ¾-in. rope, No. 16 wire; for ⅞ to 1⅛-in. rope, No. 14 wire; for 1¼ to 1⅞ in. rope, No. 12 wire; for 2-in. rope and larger No. 10 wire. Large rope should be wrapped with a seizing iron and ends securely fastened by twisting together.

In one method, ends of the wires are splayed out to a brush and embedded in zinc. For this, the second seizing is at a distance equal to the length of the basket from the end and the third one a short distance beyond. After cutting the rope to a square end, the end seizing is removed, the hemp center cut out back to the second seizing, wires untwisted and broomed out but not straightened. They are cleaned with benzine or gasoline, then dipped for not over ¾ their length in commercial muriatic acid for a minute to clean them, then into a boiling solution of soda to neutralize the acid.

Bind the wires together and insert into the basket until ends are flush with the surface, then unbind and broom out again to fill the large end of the hole. Line up the socket with the axis of the rope and seal the lower end of the basket with putty or clay.

Zinc should now be heated to not over 850 deg. F. It can be tested with a soft pine splinter. When dipped in and quickly withdrawn, no zinc should adhere or it is too cold to pour. If the stick is charred, the zinc is too hot and will anneal the wires.

Warm the socket before pouring the zinc. With the basket held vertical, pour in zinc slowly and evenly until the basket is filled, wearing a protection over face and hands while pouring.

In the second method, ends of the wires are doubled back to fill the large end of the basket. The second seizing is spaced 2¼ in. or less from the end seizing and the third the length of the basket from the second. The end of the rope is put through the socket far enough to permit working on it easily, the first two seizings removed, strands opened up and hemp core cut back to the third seizing. Strands are untwisted and wires cleaned as in the first method. Then the ends are bent in and bunched close together and the rope pulled back until the third seizing projects slightly outside the basket end.

With the socket lined up with the rope axis and held vertical, zinc is poured in to fill the spaces in the basket.

Wedge sockets, thimbles, clips and clamps are satisfactory for making connections to a rope if carefully used according to directions of the makers. Whatever method is used, strain is incurred on the rope end and it should be inspected regularly. A portion 4 to 10 ft. long from the end is likely to be affected by the stress, hence it is desirable to remove that amount and refasten the rope at intervals about 1/6 the expected life of the rope or at maximum intervals of 4 mo.

Life of Rope

Wear, corrosion and broken wires are the limiting factors. For 6 by 19 rope, the Bureau of Mines specifies discontinuance if more than six wires are broken in one lay or if surface wires are worn more than 35 per cent of their original diameter; also when surface wires are worn 30 per cent of their diameter and three wires are broken in one lay. Other conditions would be 10 per cent wear and five broken wires, 20 per cent wear and four broken wires. Manufacturers feel, however, that greater length of service is safe and, if longer life is desired, they may be consulted as to a safe length of service for any given set of conditions.

Glenwood Station Boiler Accessory Equipment

When the list of equipment installed in the Glenwood Station No. 2 of the Long Island Lighting Co., Oct. 15 issue, pp. 1012 and 1013, was published, it was not known that the blowoff valves, water gages, water gage illuminators and some expansion joints were supplied by the Yarnall-Waring Co. of Chestnut Hill, Philadelphia, Pa. Equipment for all four boilers was furnished by this company, who would have been given credit had that information been supplied with the other data on the plant.

Power Loss in Motor Connections

PROPULSION of a dinkey locomotive used for hauling material from certain mining operations to a manufacturing plant situated some distance away was by means of a storage battery and two electric motors.

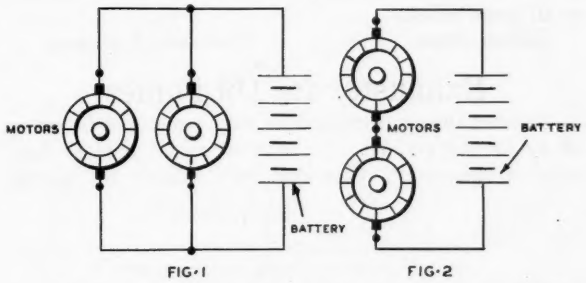


FIG. 1. MOTORS CONNECTED IN PARALLEL ON BATTERY CIRCUIT

FIG. 2. MOTORS CHANGED TO SERIES CONNECTION

The two motors were connected in parallel but, with this arrangement, the locomotive was unable to do as much work as the computed output of the battery seemed to warrant.

Thinking to improve the pulling power, the engineer in charge of the works decided to connect the motors in series, with the result that the tonnage hauled each trip was more than doubled. The improvement was explained on the assumption that, with the parallel grouping, much of the generated energy was lost in the connecting wires due to their resistance, while with the series grouping more of the energy was carried to the motors, although their speed would be somewhat less.

If the pair of motors were connected in parallel to a storage battery circuit as in Fig. 1, with resistance of the battery ½ ohm and the resistance of the wires connecting the battery to the motors also ½ ohm, the total resistance of the battery and connections would be one ohm. The battery has an open-circuit voltage of 110 v. The current for each motor was 50 amp., hence the drop due to the one ohm of resistance in the battery and connections was $1 \times 50 \times 2 = 100$ v., this leaving only $110 - 100 = 10$ v. available at the motor terminals. The power available to the two motors would be $10 \times 50 \times 2 = 1000$ w.

Now assume that the same motors are connected in series across the same battery circuit, as in Fig. 2. In this case, only 50 amp. must flow in the line in order that 50 amp. may flow through each motor. The drop due to the battery and line resistance would be only 50 v. instead of 100 v. as in the previous case, this leaving $110 - 50 = 60$ v. available at the motor terminals. The power available to the pair of motors would then be $60 \times 50 = 3000$ w. Thus three times as much power is available to the motors when they are connected in series as when connected in parallel.

It is also apparent that $110 \times 50 \times 2 = 11{,}000$ w. were given up by the battery in the first instance while only 1000 w. could go to the motors; in the second instance, $110 \times 50 = 5500$ w. were given up, while 3000 w. could go to the motors. In the one case, 10,000 w. were lost in the battery and its connections while in the other, only 2500 w. were so lost. This illustrates clearly the advantages of keeping the resistance of the connections in such installations as low as possible.

Had the combined resistance of the line and battery in Figs. 1 and 2 been only ½ ohm instead of one ohm, the conditions as regards power output would be reversed. In the case of the motors in parallel, the drop would have been $0.5 \times 50 \times 2 = 50$ v., leaving $110 - 50 = 60$ v. available at the terminals with a power available of $60 \times 50 \times 2 = 6000$ w. In the case of the motors in series, drop would have been $0.5 \times 50 = 25$ v., leaving $110 - 25 = 85$ v. available at the terminals and power available of $85 \times 50 = 4250$ w., an amount less than with the motors in parallel.

St. Louis, Mo. D. J. ALTIZER.

Brine Spray Refrigeration

REFERRING to the interesting article by J. F. Staley entitled, "Economical Small Plant Refrigeration" in the October 1 number of Power Plant Engineering, I would like to say a few words about the importance of fine spraying in brine spray systems. The finer the spray the greater the area of cold brine exposed to the air, therefore the greater the amount of heat absorbed out of the air by the brine. A large area of contact between air and brine is absolutely necessary. If the cold brine were poured into the loft in a solid stream and picked up and recirculated, the refrigerating effect would be practically nil because of the smallness of the exposed area of the cold brine. Imagine a large drop of brine, 1 in. in diam., having a temperature of 20 deg. F., being thrown into the loft. The area of a one-inch sphere is 3.1416 sq. in. and its refrigerating effect is small. Now break this large drop into exceedingly

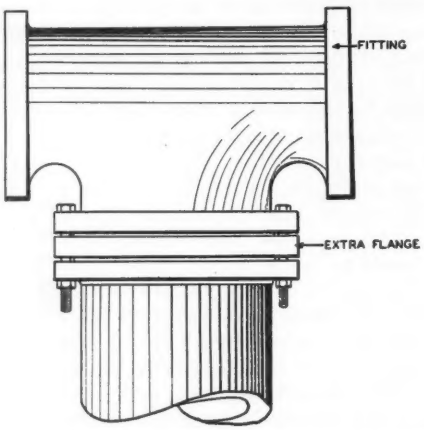
small particles, so as to have a mist. Reduce the small particles to 0.001 in. in diam. and the area of each would be 0.0000031416 sq. in. The one-inch sphere of water would be broken into one billion particles with a total area of 3141.6 sq. in., 1000 times greater after the break-up. Putting it in a different way, the area of the one-inch sphere of brine when atomized is equivalent to the area of a 1-in. pipe over 80 ft. long.

This makes it clear why high quality spray nozzles are so important—nozzles that will break the brine up into the greatest number of minute particles. The finer the particles and the greater the number of particles, the better.

Newark, N. J. W. F. SCHAPHORST.

Emergency Dutchman on a Piping Job

ON A LARGE piping job, one of those unaccountable discrepancies of fabrication took place. When a 6-in. tee was bolted in the line, it was found that the leg of



COMPANION FLANGE CORRECTED ERROR IN PIPE MEASUREMENT

the tee did not meet the corresponding flange. A space of about an inch separated the two, too much of a distance to attempt springing the piping. A 6-in. companion flange was purchased and faced off so that it made a flat ring, slightly less than an inch in thickness. This was placed between the flange of the tee and its continuing run with the necessary gaskets. Then by using extra long bolts, the job was completed.

Philadelphia, Pa. ROBERT H. BEAL.

Novel, But Sure, Test for Pipe Lines

ASCERTAINING whether or not a high-pressure pipe line is absolutely tight can be done at little cost. A high-pressure line consisting of welded and flanged joints was recently completed and tested as follows: All openings were securely blanked off. A ¼-in. tap hole was left in the end flange to which was attached an extra heavy ¼-in. bronze valve. Another blanked off opening was supplied with a ¾-in. X.H. bronze soft seat valve.

Compressed air at 200 lb. per sq. in. pressure was allowed to fill the pipe line and the usual soap suds test given to all joints. After stopping all minor leaks that showed, the air was allowed to bleed off from the pipe line.

A small steel bottle of liquid sulphur dioxide was connected to the ¼-in. valve with extra heavy flare tubing fittings and ¼-in. thick wall copper tubing. The ¼-in. valve was opened, the gas bottle valve then cracked and the gas allowed to flow into the pipe line for a few seconds. The gas bottle was then closed, also the ¼-in. valve and compressed air at 200 lb. pressure was allowed to fill the line again, the air valve closed tightly and leaks sought for with a small, open bottle of household ammonia. By simply holding the open mouth of the bottle near each joint, porous fittings, loose flanged joints, faulty valve stem packings and leaky welds will be quickly detected. A leak so small that no sulphur odor can be detected will show up as a white smoke at once when the ammonia bottle is applied to the leak.

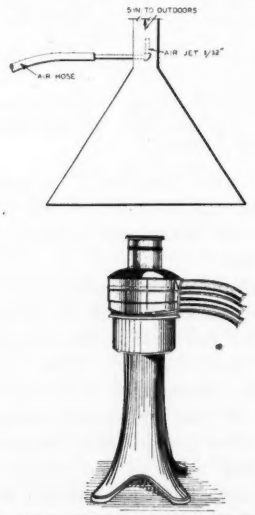
The preceding test is confined to outside use. The gas must be handled very carefully and not allowed to escape in a confined space or the liquid allowed to come in contact with the skin, or clothing. The gas is not poisonous, but it will suffocate anything that breathes it. It is, however, a wonderful agent for detecting leaks if properly handled and allowed to escape from the pipe line slowly to the outside atmosphere.

It is not recommended for a cast-iron lead calked water line. Dry anhydrous sulphur dioxide has no effect on cast iron, steel, bronze, copper or its alloys. Sulphur dioxide can be obtained in 5-10-25-50 and 125-lb. bottles in all large cities.

Boston, Mass. BRADFORD JAMIESON.

Exhauster for Oil Fumes

UNDESIRABLE FUMES such as may sometimes be given off by hot oil going to the lubricating oil purifier may cause a deposit of film that will adhere to moving



AIR JET IN HOOD PRODUCES SUFFICIENT AIR MOVEMENT TO REMOVE OIL FUMES

machine parts and other equipment in the plant. This film is especially bad on window glass, as it cuts off the light and necessitates extra labor for window cleaning. A simple and efficient method of removing these fumes is by the use of an exhaust hood of the shape shown in the illustration. From this hood the fumes can be led outside the building through a 5-in. pipe. The exhaust hood is mounted over the purifier so that it may be swung to one side. Inside the pipe an air jet will produce sufficient air movement to remove the objectionable vapors.

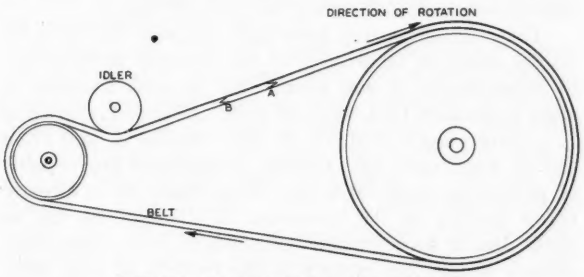
Kearney, Neb. ED. SWAN.

Questions and Answers

Which Way Should Belt Run?

CAN YOU tell me, by reference to the accompanying sketch which is the proper way to run the lap on a belt? As indicated by A?—or B?

A. A belt should always be run in such a direction that the point of the lap on the outside of the belt is pointing away from the pulley it is approaching. In other words, the joint on the belt shown in your sketch should be as indicated by A. This eliminates the tendency of the windage to open up the point of the outside lap and also prevents its catching on anything projecting near it, should the point of the lap lift.



WHICH WAY SHOULD LAP POINT?

In extreme cases where there is excessive slip on a driven pulley and where this cannot be avoided, it may be best to reverse the direction of running because the tendency of the slipping pulley is to rub up the point of the lap on the inside of the belt. This, however, is an unusual condition and need not be considered in the question as you have stated it.

Re-connecting Two-Phase Generator for Single Phase

I HAVE A two-phase 240-v. generator which I would like to rewind or re-connect for single phase 110-220 v. so that it can be used on a lighting load. The name plate rating of this machine is as follows: A.c. generator, 240-v., 60-cycle, 24-pole, 2-phase, 2-circuit, 144 coils. Can you instruct me as to how to proceed?

G. F. T.

A. It would be better to use the 2-phase winding and take single-phase power from either or both of the two phases. The rating limit for each phase would be the current carrying capacity of the coils in each phase. To connect the present winding for single-phase, 110 to 220 v. would reduce the rating and would result in poor regulation, as with single phase there would be 6 slots per pole and the resulting distribution factor, of 0.636, would reduce the terminal volts to 153 with 2 in parallel, or 306 for series connection. Then to obtain 110 or 220 v. it would further be necessary to cut out a number of coils.

With the present 2-phase winding it would be possible to re-connect the winding for dual voltage, 110 to 220, by bringing out 8 leads so that the winding could be connected externally in 2 parallels for 220 v. and in four parallels for 110 v.

This arrangement is shown in the accompanying sketch.

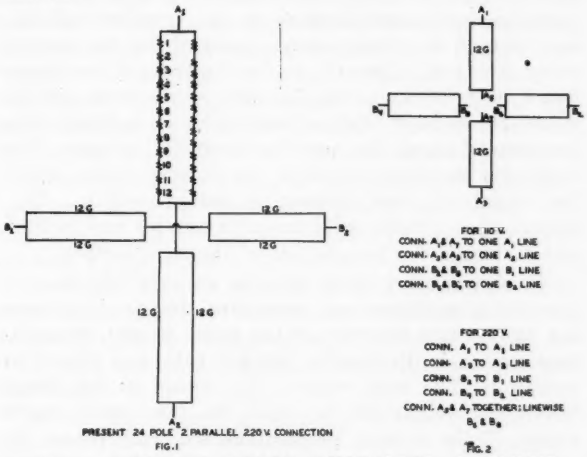


FIG. 1. PRESENT 24-POLE, 2-PARALLEL, 2-CIRCUIT CONNECTION

FIG. 2. NEW CONNECTIONS FOR 110 AND 220 V.

Thus, by opening each phase in the middle of the winding and bringing out 8 leads, the winding can be connected in 4 parallels for 110 v.

Wilkinsburg, Pa. A. C. ROE.

Steam Consumption from Indicator Card

WHY IS steam consumption greater than indicator cards indicate? 2. How is it usual to provide against breaking of cylinder head, should air pump on jet condenser stop and the water back into cylinder? 3. What is mean ordinate of indicator diagram? W. R.

A. The steam consumption is more than the indicator cards indicate because of leakage through valves and past piston and of cylinder condensation.

2. A vacuum breaker is the usual provision to guard against water backing up from the condenser into the cylinder.

3. The mean ordinate of an indicator diagram is the line representing the mean effective pressure.

ELECTRIC DRILLS, saws and other portable tools should be kept in good mechanical condition and examined frequently for possible electrical defects.

COSTS RECORDS should be accurately kept.

Editorial Comment

Vacuum Tubes, Electrons, Kilowatt-hours and The Gold Standard

More and more our lives are being influenced by that still mysterious combination of glass and metal generally known as the vacuum tube. Every day, it seems, we hear of new applications of this device. Where only a few years ago it was still a fragile curiosity used only in radio equipment, today in a multitude of forms it is being put to a thousand uses, in industry, in transportation and communication, in the treatment of disease, indeed, in almost every sphere of human activity we can think of. Recently, at the Congress of the American College of Surgeons, the aisles of the great exhibit rooms at the new Waldorf-Astoria were studded with demonstrations of the new "radio-knife" surgery—for deep cuts and light incisions, for cutting under water, for coagulating and dessicating malign growths. Surgeons show a decided willingness to use this new method and to forego the age old use of the steel scalpel.

So also in every other field the vacuum tube is revolutionizing technique and procedure. Its size is increasing daily. Just recently at the great Rugby transmitting station in England a 500-kw. tube was placed in operation. The steel, water-cooled anode of this single tube alone weighs 300 lb., while the tube itself weighs a ton! Tubes of such proportions are truly power devices and it is unquestionable but that their use will extend to power distribution and transmission purposes within the next decade or two. Direct-current transmission is merely a question of time.

New type tubes are being evolved daily. First we had direct-current tubes, then alternating and now it seems we are to have tubes with no filament at all. A new filamentless radio tube now being developed will apparently do everything the usual three electrode tube will do. Amazingly simple in construction, they can be made for a few cents each. Already they have been employed successfully in receivers and in test transmitters. At Ampere, N. J., where these tubes were developed by Dr. August Hund a single oscillating tube is in operation which is simultaneously generating three frequencies carrying three different wired radio programs.

Hand in hand with the filamentless tube is the new filamentless electric light which is said to be far more efficient than the tungsten lamp and has an indefinite life.

What part the vacuum tube will play in our lives in the future, even the most far sighted are reluctant to predict. Already X-ray tubes and cathode ray tubes operating at 900,000 volts are in use and at the Bureau of Standards recently, gamma rays were produced by means of vacuum tubes. In quite a different field of research, vacuum tubes are being applied to the preservation of food. It has been found that by means of a high-frequency electromagnetic wave, corresponding to a wave length of approximately 10 in., the life and propagation of bacteria can be destroyed and food placed within the range of this radiation is kept fresh for indefinite periods of time regardless of temperature. A small oscillator operating at such frequencies and utilizing no more power than a 50-watt lamp it is said, will protect a volume of about 30,000 cu yd. Who can say but that the time will come when a few powerful transmitters of this type will take care of food preservative throughout the nation! What will the refrigeration salesmen talk about then? And if certain waves are capable of destroying the bacteria which cause the decay of foods, it is not difficult to imagine that waves of a slightly different frequency will destroy our insect pests. Given the right frequency and with sufficient power, large sections of the earth's surface probably will be held free from the insect pests which are now so largely responsible for crop failure and famine.

These developments have their sinister side as well. At the research laboratory of the General Electric Co. in Schenectady, it was found that persons working in close promixity to a vacuum tube oscillation operating at a wave length of about six feet, became ill and from this it was found that certain frequencies are capable of producing artificial fever. This discovery is already being applied in the treatment of disease. So far so good. But if such frequencies produce fever, what happens to people that remain in the vicinity of such oscillators for appreciable periods of time? It is safe to say that it would not be good for them and might easily result in their death. Furthermore, suppose someone constructed a very powerful transmitter of this type, one rated in thousands of kilowatts, and suppose that this radiation was set free in a populous district, such as, say, New York City, what would happen to the people in that district? Here is where the little vacuum tube assumes a more formidable aspect than any other instrument of war ever devised. Fantastic? Imaginative? A wild dream? Perhaps, but not entirely without basis. The death ray of the scientific story writer may yet become a reality through the agency of the little vacuum tube.

And in yet another, totally different phase of human existence, the vacuum tube may cause great changes. Just at present there is much discussion and the foundations of the world's financial structure are being rocked by the change in our attitude regarding the "gold standard". Gold has always been an important factor in man's existence; for countless ages, man's life upon earth has been largely a fight for gold.

Well, what is gold? In the language of the scientist today, it is simply an atom with 79 electrons around the nucleus. There is not a great deal of gold in the world—all of it could be put into a cube 30 ft. on a side. This is interesting but what, you ask, has it got to do with vacuum tubes? Just this:

Like gold, lead is also an element but instead of having 79 electrons around the neucleus it has 82; and there is a great deal of lead in the world. Now, what,

asks the editor of Electronics in a recent editorial, is going to happen when comes that inevitable day that the three extra electrons will be knocked off the lead atom, leaving gold in its place? Gold then, will be only a matter of Lenard-ray tubes and high voltages; its amount merely a question of kilowatt-hours. The high priests of international finance then will have something else to think about than simply shuffling back and forth the *existing* stock of the world's 79-electron metal. Their so-called theories of the gold standard will become meaningless and we shall have a revolution of values such as the world has never seen. We may yet have solid gold turbines and platinum boilers.

Welding, a New Industrial Tool

Welding as a process is by no means new. When all metals were worked on the anvil with a hammer, one of the principal qualifications of the good smith was his ability to make a weld. In present day practice, forge welding on a large scale is used for making boiler drums and other equipment. The development of fusion welding, however, using gas flame or electric arc, has opened up a host of new possibilities not only in maintenance and installation of equipment but in manufacturing as well.

It would appear to be worth while for every power engineer at this particular time, when rehabilitation programs are being given so much attention, to devote considerable careful study to the subject. In doing so, he may discover more and more opportunities to reduce costs of maintenance and installation by the use of welding in rehabilitation work. He may find in other words, that replacement or modernizaation of existing equipment will afford opportunities to use welding that were not possible with the old equipment.

Study of the papers delivered at recent meetings of such organizations as the American Welding Society and the International Acetylene Association shows the tremendous scope and diversity of welding applications. Welding of all types of piping—steam, water, overland natural gas and oil transport piping, and many others —has received added impetus in the past few years. Development of pipe fittings for welding has brought about new possibilities. Welded structural steel framework for industrial and domestic buildings is an accomplished fact. Welded ships, welded machine parts, welded boiler drums and a host of other products may become commonplace during the next few years. We can think of no field of metal fabrication but has been appreciably modified by this new technique.

In all his applications of the new welding technique, the industrial power engineer must keep in mind, of course, the necessity for proper training of welders and for adequate testing methods. The importance of these factors has been strongly emphasized by the various organizations interested in the promotion of good welding and a great deal of information on these subjects is now available. This necessity for care in the use of welding is no greater, however, than the corresponding necessity for proper workmanship and adequate tests in all types of engineering work and it should not deter the engineer from using the technique under the proper conditions.

Thus, with industrial executives intent on reducing costs and favorably inclined toward programs of rehabilitation and modernization that will keep future maintenance costs even lower than they have been, the engineer has a splendid opportunity to consider the ways in which welding can help him to do this.

The Engineer as Purchaser

As a purchaser of power plant equipment the engineer represents a type of mind little understood by the salesman accustomed to dealing with buyers on a price or style basis. Performance, reliability and economy are three factors that enter largely into the discussion of purchases made by engineers and the salesman who is unprepared to present data pointing to superiority of his product along these lines is almost sure to meet with failure.

High efficiency is an extremely desirable quality in plant equipment but there comes a point where efficiency must give way to reliability and price. In other words, extremely high efficiencies require extraordinary attention or delicate control equipment that is likely to be expensive and difficult to keep in first class condition and, because of the extreme care required in the design and manufacture of the equipment, the first cost and the upkeep are likely to be proportionately high.

Reliability is of even more importance to the engineer than efficiency, for one failure of equipment will cost more than a few per cent gain in efficiency can make up over a long period of operation.

Economy is not a question of first cost alone but a combination of many factors including interest on investment, efficiency in operation, load factor, cost of repairs and operating expense, normal life, obsolescence and scrap value.

All of these factors the engineer takes into consideration when he makes recommendations for the purchase of equipment. Competitive equipment is subjected to direct comparison and the common arguments of salesmanship usually give way to the question of most economical equipment.

Stability of the Power Industry

If anybody has the slightest doubt that the power business is a really basic industry, the latest figures on power production issued by the N.E.L.A. and the data on industrial employment given by the Survey of Current Business should quickly dispel the doubt.

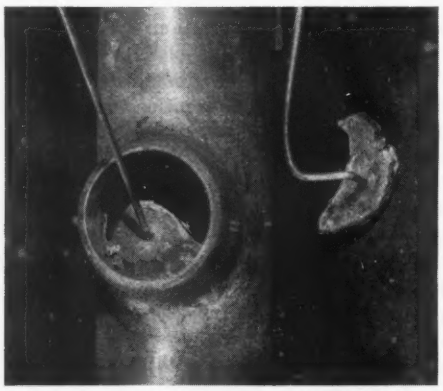
For September, 1931, the production of electricity by the public utilities in the United States reached a total of 7,080,300,000 kw-hr., only 3.5 per cent below the production for September, 1930. The production for the week ending November 7, 1931, was 1,628,147,000 kw-hr., a decrease of 5.8 per cent from the production for the corresponding week in 1930. This is extremely small, of course, when compared with the reverses suffered by other industries.

One of the best indications of the stability of the power industry is the employment situation. Taking the monthly average for 1929 as 100 per cent, the following figures for employment in various industries for the first 9 mo. during 1931 are given in per cent; power, light and water, 97; bituminous coal mining, 83.9; telephone and telegraph, 87.6; retail trade, 87.4. Taking the monthly average for 1923-25 as 100 per cent, the employment in factories for the first 9 mo. of 1931 was 76 per cent. This figure would doubtless be lowered if contrasted with the 1929 figures.

Power Plant Engineering Developments and News

Weldolets and Thredolets

TO MEET A DEMAND in the welding industry for a satisfactory method of making welded Tee junctions, Weldolets and Thredolets have recently been placed on the market by the Bonney Forge and Tool Works, Allentown, Pa. These are individual fittings designed to be installed by simply welding them to the main line, using a fusion or Vee weld, then removing the button and completing the junction by welding or screwing the branch pipe to the outlet of the weldolet or thredolet. Turbulence and friction are



REMOVING THE BUTTON AFTER THE WELDOLET IS IN PLACE

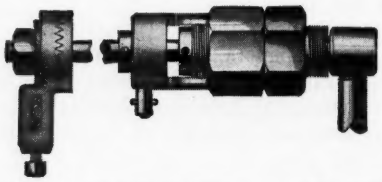
reduced by the funnel shaped outlet, it is claimed, and the fittings are designed to form strong permanent joints that are leakproof. They are drop forged, made of specially selected steel and are designed with a heavy external rib to provide strength and to dissipate the excess heat when welding, preventing any shrinkage and distortion.

After the weldolet is located in the proper position on the main line, it is tacked by welding in a sufficient number of places to insure firm contact with the main pipe. When welding, the parent pipe material, as well as the welding edge of the weldolet or thredolet, is preheated and the rod metal well puddled, to assure maximum penetration and fusion. The manufacturer states that the best practice is first to weld the fittings directly to the main line and then to remove the button, as shown in the illustration, by making an S shaped cut across the diameter of the hole and removing the button in two sections. Welding wire is tacked to each section before cutting so that it can be lifted out. After the button is removed, the welder runs his torch around the inside surface of the weldolet to smooth out any irregularities. The branch pipe is then tacked to the outlet opening of the weldolet and welded in position. If the thredolet is used, the branch pipe, of course, is threaded to fit. Weldolets are made in standard stock sizes as follows: pipe size 1 to 12 in., outlet sizes ½ to 10 in. Thredolets are made in pipe sizes from 2 to 12 in., outlet sizes ½ to 6 in.

Ball-Bearing Stuffing-Box

STANDARDIZATION on a new type ball-bearing stuffing-box is announced by the Fisher Governor Co., Marshalltown, Ia. This new development is an unusually compact device and will be a standard feature on all float cages and rotary lever valves of Fisher manufacture.

Stainless steel is used in the stem, nut, and body of this stuffing-box. Highest quality steel ball bearings are assembled in the ball-bearing unit, which is



BALL BEARING STUFFING-BOX OF THE FISHER GOVERNOR CO.

sealed and kept lubricated by an Alemite greasing connection. The ball-bearing unit which is sealed is made of the highest quality steel used in the manufacture of bearings in order to insure long life and a high load-carrying bearing.

A modern method of renewing packing is provided, allowing the operator ample space to work, but not disturbing any connections to the rotary stem. A large recessor chamber allows considerable packing storage. Longer life and less frequent packings are the advantages gained.

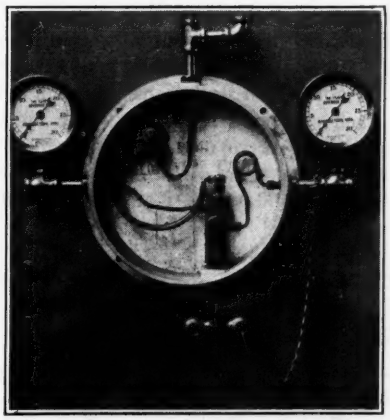
The rotary stem, which is made of highly polished stainless steel, is particularly small in size in order to eliminate excess packing friction. The use of combination radial and thrust ball bearings offers a sturdy support for the float stem, which reduces side throw or motion to a minimum. Closer regulation is obtained as the result of smoother action.

Among the additional features of construction which can be embodied with the stuffing-box is the liquid seal unit for vacuum service. A positive liquid seal in the lantern ring, which is between two halves of packing, eliminates the possibility of air being

drawn into the system. By changing to a screw plunger greasing fitting, this stuffing-box can be converted to a lubricated unit, allowing a suitable grease lubricant to be supplied to the lantern ring, this keeping the packing well lubricated. For oil service, a grease cartridge that is insoluble in petroleum fractions is used.

Bourdon Tube Pilot Valve Control

LATEST addition of the Fisher Governor Co., Marshalltown, Ia., to its line of specialty products is the new pilot valve control known as the Type 4000. Close control, fully throttling in action, and the elimination of all mechanical lag are the points of merit of this new device. It meets the ever-growing demand for sensitive regulation. The use of diaphragm and spring is eliminated, the change of the leak of the operating medium (air or gas) being accomplished by the varying position of the Bourdon tube which is, of course, a function of the pressure therein. This tube is suspended free in the control with the resultant elimination of all contacts and friction.



FISHER GOVERNOR CO., TYPE 4000 PILOT VALVE CONTROL

Flexibility in construction allows a change from direct action to reverse action in the minimum of time, thus changing a pressure control valve to a back pressure valve or vice-versa without trouble or delay. A change of pressure range is made by a change of Bourdon tube. Any control unit can be changed from a low-pressure control to any range up to 2500-lb. control pilot by fitting with a suitable Bourdon tube.

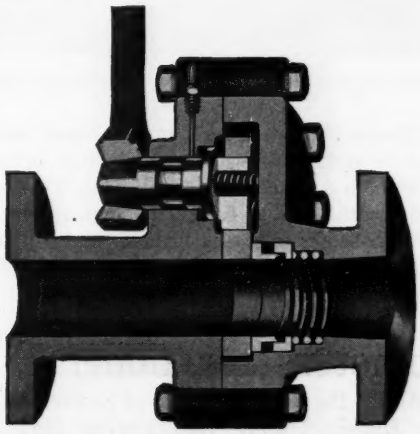
Neat appearance is fostered by an aluminum case, which can be placed on an instrument panel for remote control. The pilot control is furnished complete with gages and auxiliary operating medium pressure regulator. This type of control finds ready adaptation in reduced pressure, back pressure, boiler gas fuel, and vacuum control. A modification can be furnished for control of differential pressure.

NEW ORDERS booked during the 3rd quarter of 1931, as reported to the Bureau of the Census by 84 manufacturers of electrical goods, were $157,471,784, as compared with $224,347,794, for the 2nd quarter of 1931, and $228,732,926, for the 3rd quarter of 1930. Bookings include motors, storage batteries, domestic appliances, and industrial equipment.

New Straight Flow Valve

YARWAY Pretite Valves form a new line recently developed by Yarnall-Waring Co., Chestnut Hill, Philadelphia, Pa., for general service use. These new valves are somewhat similar to the well known Yarway Double Tightening Valve, of the quick opening, lever operated, swing gate type having a straight throw flow and the unique feature of a new two-piece sealing bushing on the inlet side so that, as its name implies, it is pre-tight.

This new two-piece construction of the sealing bushing provides a positive, automatic packing adjustment.



YARNALL-WARING CO., NEW PRETITE VALVE

A heavy corrosion-resisting spring keeps the sealing bushing up against the disc or gate when no pressure is applied. The sealing bushing is forced up tight against the machined surface of the gate by the line pressure, this pressure being applied only on the annular area on the end of the sealing bushing which is not against the disc. The sealing bushing is continually ground in, just as the opposite face of the one piece solid disc is ground in as it passes across its seat. This solid disc or gate is in positive contact with its two seats during the entire opening and closing cycle.

The Yarway Pretite Valve is fully lubricated by means of Alemite fittings, with the grease properly guided to the sliding surfaces. These valves are made in various materials and in sizes from ½ to 4 in. inclusive.

Asphalt Plank for Roadway Platform

COMPOSED of high grade asphalt, selected binding fibers, and Celite, J-M asphalt bridge plank is a recent development of Johns-Manville Corp., 292 Madison Ave., New York. It is a light weight, durable, long lived, resilient, waterproof plank, which can be laid rapidly at small cost and which will require little maintenance. It is intended for use in roadways, loading platforms and similar service; weighs about 7 lb. per foot-board measure or about 85 lb. per cu.ft., about half the weight of concrete and far below the average of the usual mixture of mineral and asphalt or tar commonly used for this service. It is not affected by heat or frost,

LAYING JOHNS-MANVILLE CORP. ASPHALT PLANK

will not freeze or disintegrate, carries heavy loads without fracture and is self-healing. It is made in widths of 8 and 10 in., and in thicknesses of 1, 1¼, 1½ and 2 in., standard lengths of 3 and 6 ft. although special lengths can be furnished. No special tools beyond a plank jack, chisel or hatchet and hammers are required for laying the pavement.

Pyrometers for Boiler Plants

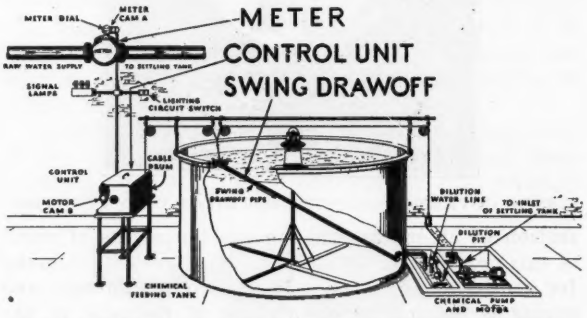
TO MEET the exacting needs of power plant work, the Illinois Testing Laboratories, Inc., 141 W. Austin Ave., Chicago, Ill., have developed the Alnor model H pyrometer with a long, horizontal, easily read scale. This model has unusually high torque for its high internal resistance, thus assuring permanence of accuracy under severe operating conditions. The case is water-tight, fume- and dust-proof and can be used under any atmospheric condition without the necessity of enclosing it in an expensive housing. It is furnished complete with 10 ft. of alloy connecting wire, a connector block and a No. 8 gage thermocouple 24 in. long.

PORTABLE PYROMETER OF THE ILLINOIS TESTING LABORATORIES, INC., IN USE

Another development for testing, supervision, investigation and experimentation is the Alnor portable pyrometer or thermo lance. This is an extremely handy self-contained, portable pyrometer of sturdy construction particularly adapted for boiler room use. One of these units is shown in use by the illustration. Its small size enables it to fit into narrow spaces between boilers, on top of the setting, and at the back or in the breeching to measure temperature of difficult places and to seek out heat losses that are unseen and unknown.

New Chemical Feeder

TWO ELECTRO-CHEMICAL feeding systems known as type B and type D have been developed by the Permutit Co., 440 Fourth Ave., New York City. Type B illustrated below is generally used in connection with lime, soda and similar plants, while type D is particularly suitable for installations in which acid feed is used. In each system a standard water meter with a cam attached is used to measure the flow of water to the unit and to make the electrical contacts which furnish the impulse to start the motor of the control unit.



ARRANGEMENT OF THE TYPE B ELECTRO-CHEMICAL FEED OF THE PERMUTIT CO.

In type B, the control unit functions to raise or lower a swing draw-off pipe in the chemical feeding tank. In this way, it regulates the amount of chemical feed to the dilution tank. The motor cam B is rotated through a separate pawl and ratchet drive so that its speed can be set as desired. By means of this adjustment, the time period of the motor operation following each meter impulse can be controlled by setting the speed of the cam.

This setting determines the volume of chemical feed per unit volume of water passing the meter irrespective of the rate of flow of water. Several sets of chain gears are supplied with each control unit and by changing the gear ratio the rate of feed can be varied over a wide range but, once the correct gear ratio has been selected, ordinary variations in chemical dosage can be obtained by adjusting the throw of the crank.

FOR HORIZONTAL or vertical drives of ⅛ hp. and over, a two-speed worm gear reduction with Timken roller bearings, all encased and running in an oil bath, has been introduced by Gears & Forgings, Inc., of Cleveland, Ohio. Speed change ratios are from 4 to 1 up to 150 to 1, the two speed being obtained by differential gears operated by a hand lever, changeable while under full load.

Ice Plant Model Shows Modern Equipment

ENGINEERS AND plant managers attending the conventions of the National Association of Ice Industries and the National Association of Practical Refrigerating Engineers, this year, had an opportunity to study the scale model of a 50-t. dual pressure ice plant. The model, exhibited by the Frick Co., Waynesboro, Pa., measures 70 in. long by 40 in. wide by 34 in. high, and is an accurate reproduction of the latest type of group lift-plant. A hinged panel at the end of the tank discloses a miniature vertiflow unit evaporator; at the opposite end of the tank appears a can filler of the measuring pressure type. A little crank on the end of the crane allows the grid of 12 cans to be dumped. The condenser shown above the ammonia receiver is of the horizontal multi-pass type. A float valve mounted just below the accumulator, an agitator, low-pressure air blower and core pumping set complete the standard ice making equipment.

Water and liquid ammonia precooling apparatus is shown in the pent house on the roof. A second float control feeds ammonia to the zigzag water cooling coils and the "boiler" shell in which the liquid precooling coils are located. The high-pressure suction line from this equipment comes into the compressor from the right.

New Portable Belt Conveyor

FEATURES of the "Cub" portable loader, which has recently been entirely redesigned by Link-Belt Co., Philadelphia, Pa., are: Reduction of 100 lb. in weight without sacrifice of strength or durability; conveyor belt 18 in. wide with 21-ft. centers and return run covered by channel frame; 9-in. head pulley driven by electric motor through cut gears and a short chain, using motor ball bearings, bronze-bushed shaft bearings, and roller bearings on troughing rollers; worm and wheel for raising and lowering delivery end with self-locking feature; sharp-pointed nose at the foot with belt-lining guide; for coal-yard and special use, screening chute or hinged trough plates; roller bearings on shifting wheels.

CHAMPION AND BARBER, INC., Los Angeles, announces two new gage-protection products, the Champion Gage Protector and the Champion Non-Pulsator. These have been developed to give complete protection of all makes of gages under every operating condition.

The Champion Gage Protector is a three-part, bronze-bodied, rubber-bulbed pressure transmitting instrument, used to transmit line pressures to gages recording by a secondary, or bulb pressure. Recordings are the result of the compression of the secondary bulb liquid by a given line liquid. It has an anti-corrosive body, an acid resistant pressure bulb and is built to restrict the passage of line solids into the gage or tube movement, and to make an all-purpose gage out of any ordinary gage.

The Champion Non-Pulsator operates by fluid passage restriction and the control of the restriction by means of a needle valve. Pulsation recordings on the gage are controlled entirely by the adjustment of the needle valve, it is stated, regardless of the pulsations of the line pressures.

News Notes

SPRINGFIELD BOILER CO., Springfield, Ill., announces that it is prepared to furnish and accept complete responsibility contracts covering complete steam generating units, including Springfield boilers and water walls and permitting the purchaser to make his own selection of all auxiliary equipment.

A. W. THOMPSON, who for the past five years has been Pacific Coast manager in charge of sales for Fairbanks, Morse & Co., has been appointed vice-president in charge of manufacturing, according to an announcement made public by W. S. Hovey, president. Mr. Thompson succeeds Mr. Heath, who resigned November 1.

Mr. Thompson graduated with an engineering degree from the Rennselaer Polytechnic Institute in 1907. Upon his graduation he became associated with the George A. Just Co. of

New York City and later with Westinghouse, Church, Kerr & Co., with both of which he had both engineering and sales experience.

In 1910 he made a connection with the General Electric Co. and remained there for 10 yr., during which time he was in charge of the design and development of the Erie Works of that company.

In 1920 Mr. Thompson joined the Fairbanks-Morse organization as general manager of the Indianapolis plant and in 1926 he was transferred to San Francisco as Pacific Coast Manager in charge of sales. In 1928 he was made a vice-president.

WHITING CORP., Harvey, Ill., through its subsidiary, the Grindle Fuel Equipment Co., has just secured the services of C. F. Herington as sales engineer. Mr. Herington has had 28 yr. experience in engineering work, including 6 yr. with Westinghouse, Church, Kerr & Co., 7 yr. with the New York Central and Pennsylvania R. R., and for the past 15 yr. has been engaged in selling pulverized coal plants. During the last 9 yr. he has been affiliated with Heyl & Patterson, Inc., of Pittsburgh, Pa., where he had charge of engineering, selling and erection of pulverized coal plants such as the Erie Malleable Iron Co., the Raritan Copper Works at Perth Amboy, N. J., the smelter of the International Nickel Co. of Canada, also equipment for the smelters of the Union Minere du Haut Katange in Africa and the Nouvelle Foundry in Belgium.

UNION CHAIN & MANUFACTURING CO., Sandusky, Ohio, has recently appointed C. H. Upson, 1012 Traction Building, Cincinnati, Ohio, representative in that territory.

AMERICAN MANGANESE STEEL CO., Chicago Heights, Ill., states that its Chicago office has been moved from 333 North Michigan Ave. to Room 1414, McCormick Building, 332 S. Michigan Ave.

JOHN D. BALL, who was chief engineer for Louis Burk Packing Co., Philadelphia, for many years, died recently. He was generally considered to be the original organizer of the Vulcan Assembly in Philadelphia and was active in a number of other organizations.

FOSTER WHEELER CORP. of New York City announces the opening of a branch office in Washington, D. C. This office will be equipped to handle inquiries for all products of the Corporation. J. S. Malseed, a sales engineer of long experience, has moved from New York to Washington and will be in charge of the new office. The address is 726 Jackson Place, N. W., and the telephone number—National 9206.

Books and Catalogs

REFRIGERATION SERVICE MANUAL. By L. K. Wright. Published by Gernsback Publications, Inc., 96-98 Park Place, New York, N. Y. Flexible fabricoid, 9 by 12 in., 352 pages. Price, $5.00.

Prepared especially for the maintenance and servicing of small refrigeration units, this book begins with a short history of refrigeration followed by chapters on fundamentals of refrigeration, refrigerants and their properties; service tools and shop equipment; trouble shooting; motors and unit parts. Operation of the plant, each piece of equipment, defrosting, testing for leaks and similar subjects are covered in great detail. The balance of the book, about 75 per cent. is devoted to a detailed description with operating directions for practically all small commercial machines, ice boxes and water coolers.

1931 BOOK OF A.S.T.M. TENTATIVE STANDARDS, published by the American Society for Testing Materials, 1315 Spruce St., Philadelphia, Pa.; 6 by 9 in., 1008 pages. Price, cloth. $8.00; paper, $7.00.

This volume contains 180 tentative standards divided as follows: ferrous metals 25; non-ferrous metals 15; cement and related products 30; preservative coatings 34; road and paving materials 25; rubber, insulating and textile materials 30; miscellaneous 21. This list includes 41 new standards developed this year. Although these tentative standards are in the trial stage of A.S.T.M. procedure (the procedure being to publish them for one or two years to elicit criticism) they represent the latest thoughts of the committee on these specific subjects and are being applied in many industries frequently in conjunction with other A.S.T.M. standards. There is a comprehensive subject index and in addition a complete list of all the standards and tentative standards in effect September 1.

THE AMERICAN SOCIETY FOR TESTING MATERIALS, Philadelphia, Pa., has issued the 1931 Supplement to the 1930 book of A.S.T.M. standards. The book of standards is issued every third year and standards which are adopted by the Society in intervening years are published in supplements which bring the main book up to date. This supplement has 144 pages. Of the 32 standards adopted or revised by the Society this year, 17 are new standards and 15 are replacements; 7 of the 32 relate to metals and 25 relate to non-metallic materials. The main book together with the supplement contains a total of 443 standards which are now in effect. A complete list of these is given in the back of the supplement.

STRUCTURAL STEEL REPORT, Welding Committee, American Bureau of Welding. 6 by 9 in., 208 pp., paper cover, 1931. Price, $1.

This report constitutes a complete record of the activities to date of the committee organized in 1926 for the purpose of "obtaining reliable information upon which to base safe unit working stresses in the designing of welded structures."

After reviewing all of the test data in the literature available at that time, the Committee concluded that a comprehensive series of tests should be made before final recommendations were promulgated. An investigation was therefore undertaken, the principal objects of which, after some modifications during the progress of the work, were the determination of: 1. Safe design values under static loading for various types of fusion welded joints as commercially welded in structural steel fabricating shops. 2. The degree of uniformity of the strength of welded joints that may be expected from such shops throughout the country.

In order that the results of the investigation should be thoroughly representative of commercial practice, a large number of shops were invited to participate. To insure the maximum uniformity of procedure in the conduct of the tests, comprehensive instructions were prepared covering all details from the selection of the welders to the preparation of test reports by the coöperating laboratories. The final program as carried out and reported included the welding and testing of 1098 specimens in connection with the qualification of the welders and 1395 specimens in connection with the investigation proper—the latter involving 55 elemental forms of joint in 169 sizes. Participants in the investigation included three steel mills, 39 fabricating shops, 61 welders, 18 inspectors, and 24 testing laboratories distributed over the central and eastern portions of the United States. A Canadian laboratory provided pilot or preliminary information based on the testing of 342 specimens welded in three Canadian shops. About five years have been spent on the entire investigation.

Final conclusions of the Committee with respect to its two principal objects of investigation, are: 1. The following permissible unit stresses, in kips (thousands of pounds) per sq. in. of weld throat, specified in the American Welding Society's "Code for Fusion Welding and Gas Cutting in Building Construction," shear, 11.3; tension, 13.0; compression, 15.0, are safe and reasonable and are indorsed, provided the welder has been qualified and provision has been made for bending stresses that may be introduced due to eccentricity. 2. In commercial practice a welded joint may be expected to have a strength within 12 per cent of a general average for that type of joint, provided the welder has attained the stated qualifications.

The important requirement in that Code with reference to making adequate provision for bending stresses due to eccentricity can be met in a practical manner by a division of joints into two classes, those having negligible and those having considerable eccentricity. Simple characteristics are given in this report whereby a proper classification may be made.

This report points out that the Committee's conclusions are necessarily based on the behavior of the particular specimens investigated and, with a view to extending the scope of its conclusions, a number of desirable fields for further research are recommended.

The report is a volume of 208 pages bound in a serviceable cover, with subject matter divided into ten sections and cross referenced. The Committee's expressed aim for a high degree of legibility in tabular and charted matter has been well achieved in the 54 cuts and 18 tables which illustrate the report. A table of contents and a comprehensive alphabetical index add to the usefulness of the report.

PYRO-MORTAR, a dry refractory bonding mortar for high temperature work, is completely described and illustrated in a new bulletin issued by Quigley Co., Inc., 56 West 45th St., New York City.

DESIGN of shell-and-tube heat exchanger which has been developed by The Griscom-Russell Co., is of particular interest because of the absence of cross baffles in the shell. Such baffles have heretofore been necessary, it is stated, in order to secure the velocity and turbulence through the shell required for high heat transfer rates. In the G-R Equaflo exchanger a special form and spacing of the tubes is employed to equalize the total tube and shell cross-sectional areas so that the same velocities of hot and cold fluids are obtained without cross baffles in the shell. These exchangers are applicable to heat transfer services in petroleum refineries, chemical plants, and special process work where the hot and cold liquids or gases are of approximately the same quantities. The special features of this apparatus are outlined in a bulletin which has just been published by The Griscom-Russell Co., 285 Madison Ave., New York City.

TYPE GA COMMERCIAL Single-Cylinder Gas Engine and Type GA Commercial Twin-Cylinder Gas Engine are the respective titles of two 12-page bulletins just issued by The Cooper-Bessemer Corp., Mt. Vernon, Ohio. The first bulletin deals with the convertible gas or oil engine rated 25 to 60 b.hp. The second bulletin covers the convertible gas or oil engine rated 65 to 130 b.hp. Both engines are the slowspeed, horizontal, 2-cycle type.

TYPE H STIRLING BOILER, designed for high steaming capacity for the low headroom and floor space required, is described in a new bulletin by The Babcock & Wilcox Co., 85 Liberty St., New York.

The booklet contains full descriptions and setting plans showing installations of the boiler in widely diversified industries, using many different types of firing.

PARKER SERVICE FITTINGS and copper tube are described and illustrated in a recent 10-page folder by Parker Appliance Co., 10320 Berea Road, Cleveland, Ohio.

CARNEGIE STEEL SHEET PILING, plain rolled with thumb and finger type interlocking joint, is completely described and illustrated in a recent 92 page letter-size bulletin issued by Carnegie Steel Co., Pittsburgh, Pa. The bulletin gives complete details regarding the various types and sizes of this piling, detailed drawings showing the various ways in which it can be used, together with much interesting engineering information on design of various structures to which it can be applied. Discussion is given of its use in building foundations of power plants, docks, breakwaters and other engineering structures.

BAROMETRIC DRAFT CONTROL, fully automatic, as described in the July 1, 1931, issue of Power Plant Engineering is further described and illustrated in a series of bulletins just issued by the manufacturer, Field Mfg. Co., Chicago, Ill. The Chicago Fuel Saver Co., 5510 Broadway, is the distributor of this product. Several of the above bulletins contain reports of boiler tests showing fuel consumption and other related information before and after installation of the draft control equipment.

COMPLETE DETAILS of the new Brown Potentiometer Pyrometer are given in a recent publication of the Brown Instrument Co., Philadelphia, Pa. This describes the instrument in detail showing the construction of the galvanometer, slide wire, pen drive and clutch, humidity compensator and other features, discussing the advantages and applications of the instrument to the measuring of temperatures in industrial plant work.